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Issued November 9, 1912.

U. S. DEPARTMENT OF AGRICULTURE.
FOREST SERVICE—BULLETIN 118.
HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

PROLONGING THE LIFE OF CROSSTIES.

BY

HOWARD F. WEISS,
Assistant Director, Forest Products Laboratory.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

FOREST SERVICE.

HENRY S. GRAVES, *Forester.*
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., July 8, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Prolonging the Life of Crossties," by Howard F. Weiss, Assistant Director, Forest Products Laboratory, and to recommend its publication as Bulletin 118 of the Forest Service. The more recent experiments, the results of which are discussed, were carried on at the Forest Products Laboratory maintained in cooperation with the University of Wisconsin.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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PROLONGING THE LIFE OF CROSSTIES.

SCOPE OF THE BULLETIN.

This bulletin brings together the results of experiments of the Forest Service in prolonging the life of crossties.[1] The data presented are taken from previous publications of the Service and from many unpublished reports of field and laboratory tests.[2] Three phases of the subject are discussed: (1) Treating the wood with chemical preservatives; (2) protecting the ties from mechanical wear; and (3) the use of sawed in place of hewed ties. It is by these three means that the enormous annual consumption of crossties in the United States can be reduced by at least half, with an annual saving to the railroads of at least $16,000,000.

In 1909 the steam and electric railroads of the United States purchased 123,751,000 wooden crossties at a cost of $60,320,700. Of these ties, 16,437,000, or about 13 per cent, were purchased for new construction;[3] the remainder, 107,314,000, were used for renewals. This means that throughout the United States, on an average, about 358 ties were removed from every mile of track, which, at an average price of 49 cents per tie, necessitated, exclusive of all labor, a charge to the railroads of about $175 per mile, or $52,500,000 for all lines in operation. To produce the ties used for renewals it was necessary to cut about 710,000 acres of timberland, averaging 5,000 board feet or 150 ties per acre. The amount of wood so cut is equivalent under present conditions to the annual growth on about 55 million acres of forest.

PREPARING TIES FOR PRESERVATIVE TREATMENT.

Ties must be thoroughly seasoned before treatment with preservatives if the best results are to be secured. The first step in the process is to remove all bark adhering to the ties.

[1] Acknowledgment is due Mr. F. J. Angier, superintendent of wood preservation, Baltimore & Ohio Railroad; Mr. Carl G. Crawford, general manager American Creosoting Co.; Dr. W. K. Hatt, professor of civil engineering, Purdue University; and Mr. E. A. Sterling, consulting forest engineer, for assistance rendered in reviewing this manuscript before its publication.

[2] The authors of the unpublished reports from which data were taken are Messrs. C. H. Teesdale, E. W. Peters, P. R. Hicks, H. B. Oakleaf, J. A. Newlin, H. F. Weiss, C. P. Winslow, and M. C. Jensen.

[3] Bureau of the Census, Department of Commerce and Labor, Forest Products No. 8, 1909.

PEELING.

The removal of bark hastens seasoning and permits uniform drying. Where an oil like creosote is used as a preservative, the presence of bark on the ties may result in such erratic penetration and absorption as to make the efficiency of the preservative practically zero.

Some pine ties treated at Birmingham, Ala., were simply slabbed on two sides and permitted to season with the bark on. After three months' exposure to the air the ties were peeled and treated. The creosote penetrated only about 1 inch from the sides of the ties where the bark had adhered and more than 2½ inches from the slabbed faces, thus forming two V-shaped zones of treated wood (Pl. I, fig. 1). Had

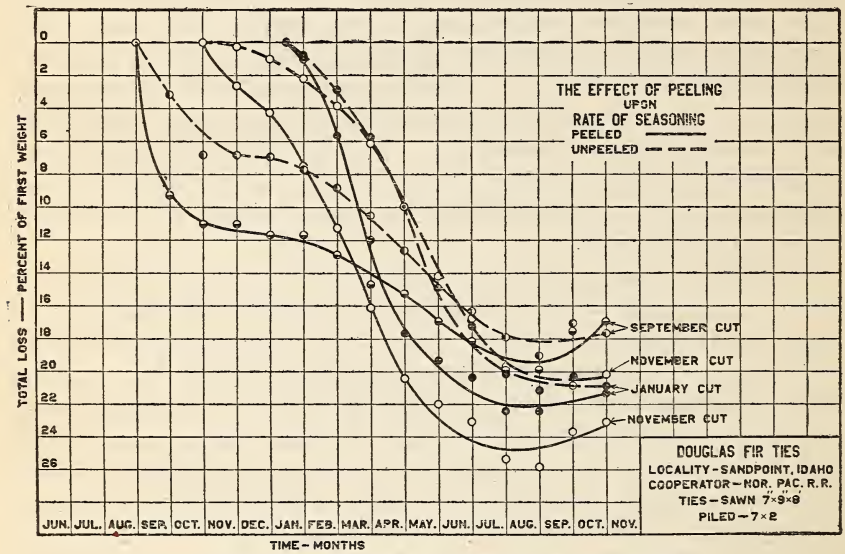

FIG. 1—Effect of peeling on the rate of seasoning of Douglas-fir ties.

all the bark been removed when the ties were cut, seasoning would have been uniform and impregnation complete, except for a core of heartwood in the center about 1 inch in diameter. The effect which a thin strip of bark adhering to a thoroughly air-seasoned pine tie may have on its absorption of preservative is shown in Plate I, figure 2. This strip of bark, which was about 0.75 inch wide and as thin as paper, absolutely prevented the entrance of creosote and resulted in a strip of untreated wood from the surface to the center. As a rule, penetration is much greater with the grain than across it, and in some kinds of ties, therefore, the presence of a small amount of bark is of little importance. The same is true when salt solutions, such as zinc chloride, are used as preservatives, since not only are comparatively large quantities of these usually injected into the wood, but they permeate the wood fibers better than oils.

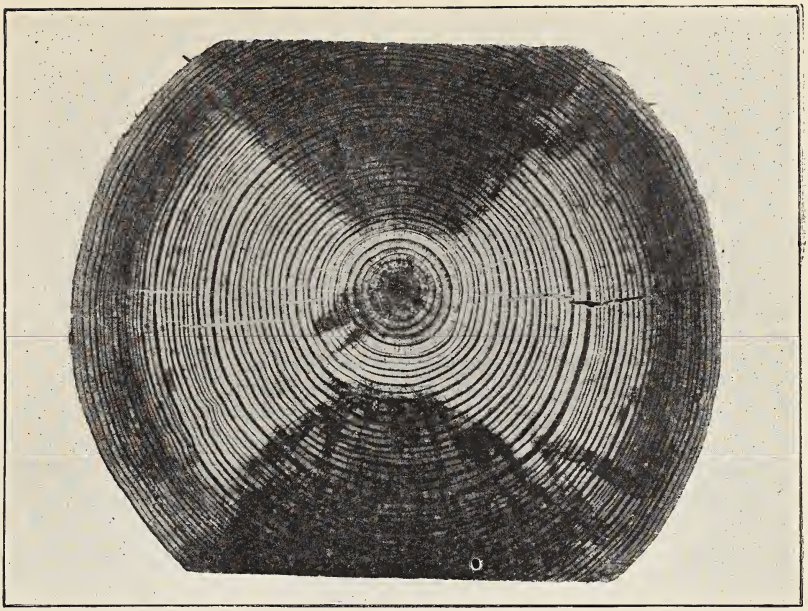

FIG. 1.—UNEQUAL PENETRATION OF CREOSOTE IN AN AIR-SEASONED SHORTLEAF PINE TIE. ALL BARK WAS REMOVED JUST BEFORE TREATMENT.

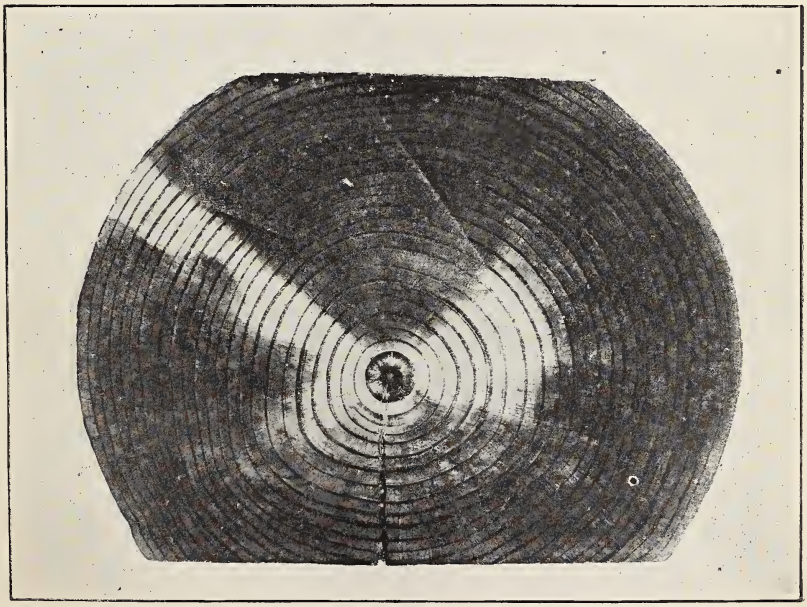

FIG. 2.—EFFECT OF A THIN STRIP OF INNER BARK IN RESISTING PENETRATION BY CREOSOTE OF AN AIR-SEASONED SHORTLEAF PINE TIE.

Ties peeled in summer sometimes dry too rapidly and so "case-harden," which increases the difficulty of securing penetration of the preservative. Of a number of hemlock ties tested at Escanaba, Mich., in cooperation with the Chicago & Northwestern Railroad, most were peeled after seasoning. With the Burnett treatment these absorbed 6 pounds more of the solution than those peeled when cut.

The best time to peel ties, however, is an economic question which must be determined for each particular case. As a general rule, it is good practice to remove the bark as soon as possible after the ties are cut, and to regulate the rate of seasoning by methods of piling. In this way peeling will be easier, there will be less danger from insects, and seasoning will be more rapid.

SEASONING.

Of the three common methods of seasoning, namely, by air, by steam, and by oil, the first is the best, if conditions will permit its use. Often, however, a treating plant is called upon to fill a rush order when its stock is insufficiently seasoned for treatment, or the plant may be so located that it can not keep a large stock of air-seasoned material on hand. In such cases artificial seasoning must be practiced.[1]

AIR SEASONING.

In air seasoning the following considerations are important: (1) Kind of wood, (2) temperature and circulation of air, and (3) manner of piling.

Kind of wood.—Coniferous woods, such as pines, firs, and spruces, season faster than many hardwoods, and because of their more uniform structure are easier to dry and can be piled more openly without danger of serious checking. The rates at which different kinds of ties season at different periods of the year are shown in figures 2 to 12. The data on which these curves were based were gathered during several years' investigation and include thousands of weighings. The figures show how marked is the difference in the rate of seasoning of such species as loblolly pine and red gum in comparison with red and white oaks. Loblolly pine and red gum ties cut in summer lost 62 and 63 pounds, respectively, in about 3 months, while red oak ties lost only 25 pounds and white oak 10 pounds during the same period. In other words, gum and loblolly ties lost from $2\frac{1}{2}$ to 6 times as much water as those of red and white oak.

Temperature and circulation of air.—The warmer and drier the air and the greater its circulation, the more rapid will be the loss of

[1] A more thorough discussion of seasoning is contained in Forest Service Bulletin 41, "Seasoning of Timber," by Hermann von Schrenck.

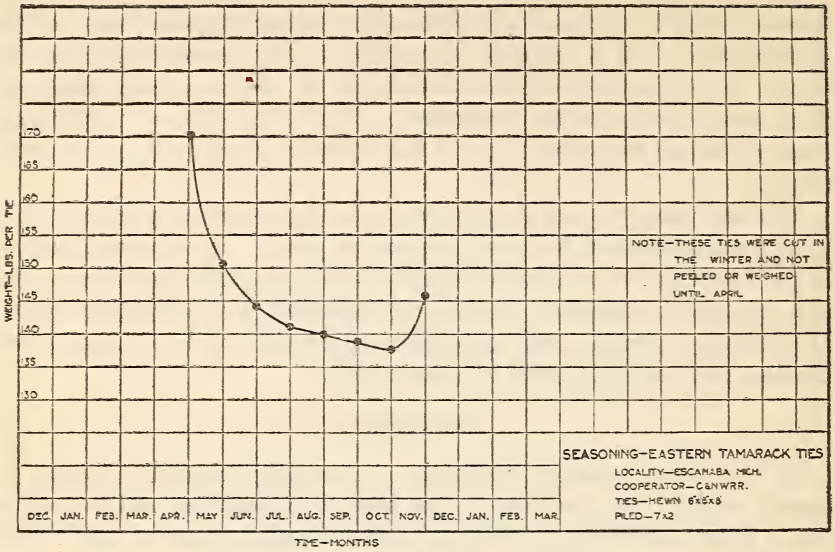

FIG. 2.—Rate of seasoning of eastern-tamarack ties.

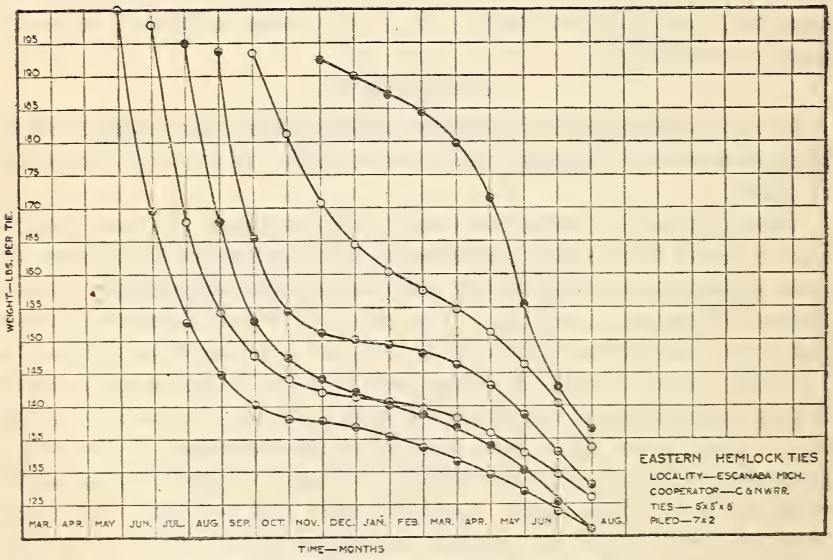

FIG. 3.—Rate of seasoning of eastern-hemlock ties.

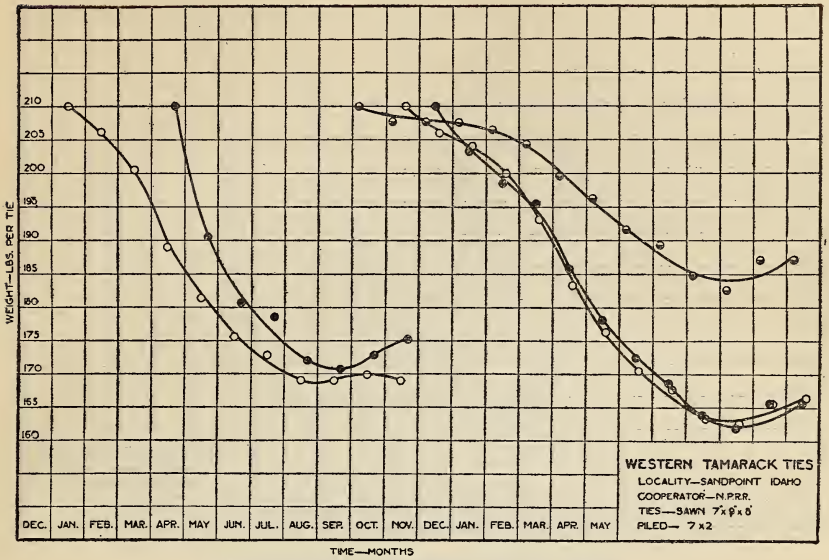

FIG. 4.—Rate of seasoning of western-tamarack ties.

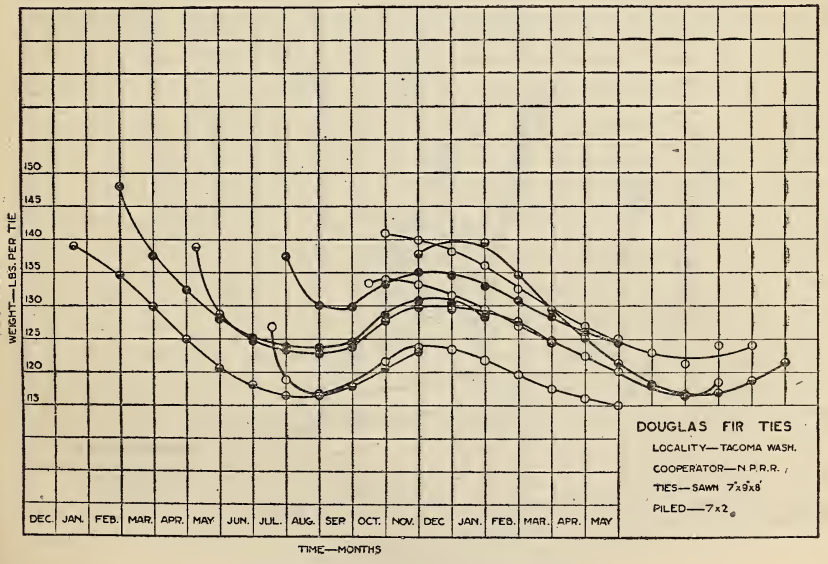

FIG. 5—Rate of seasoning of Douglas-fir ties.

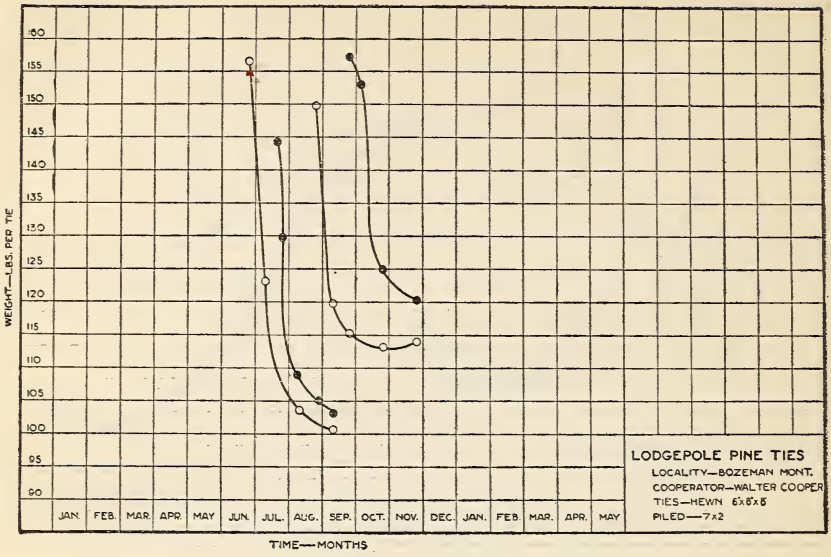

FIG. 6.—Rate of seasoning of lodgepole-pine ties.

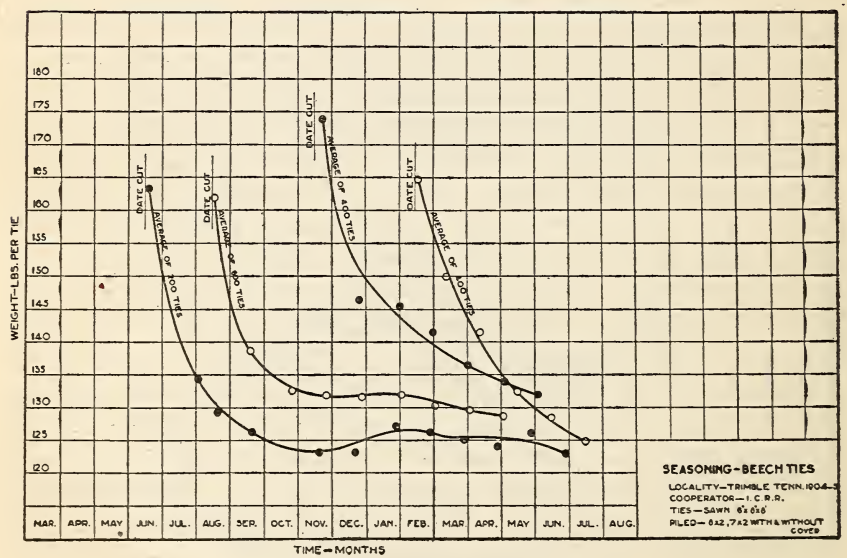

FIG. 7.—Rate of seasoning of beech ties.

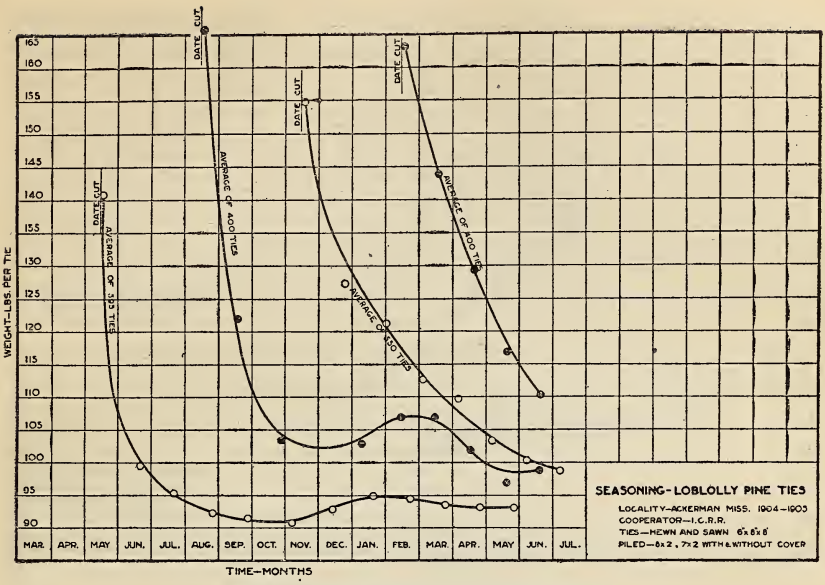

FIG. 8.—Rate of seasoning of loblolly-pine ties.

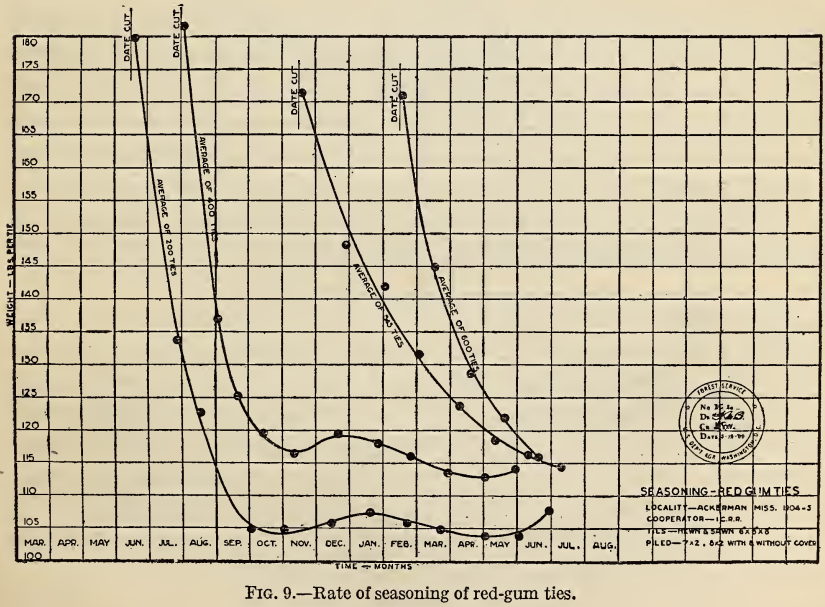

FIG. 9.—Rate of seasoning of red-gum ties.

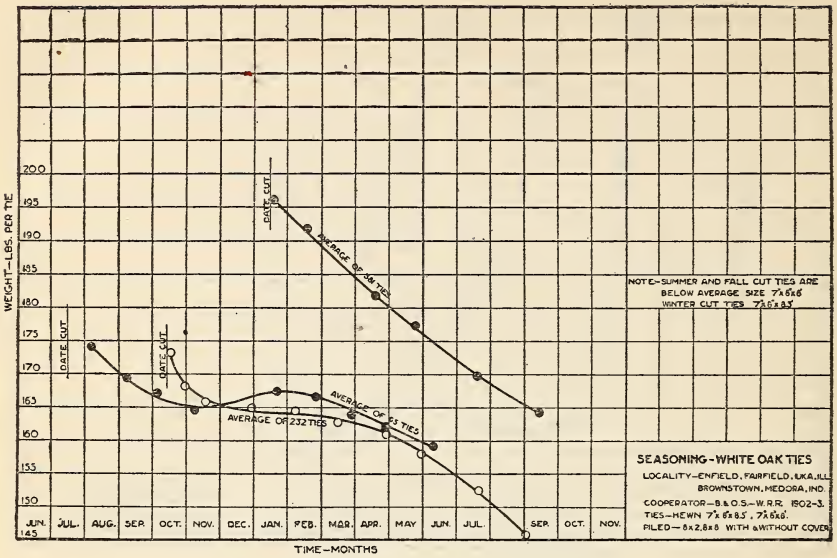

FIG. 10.—Rate of seasoning of white-oak ties.

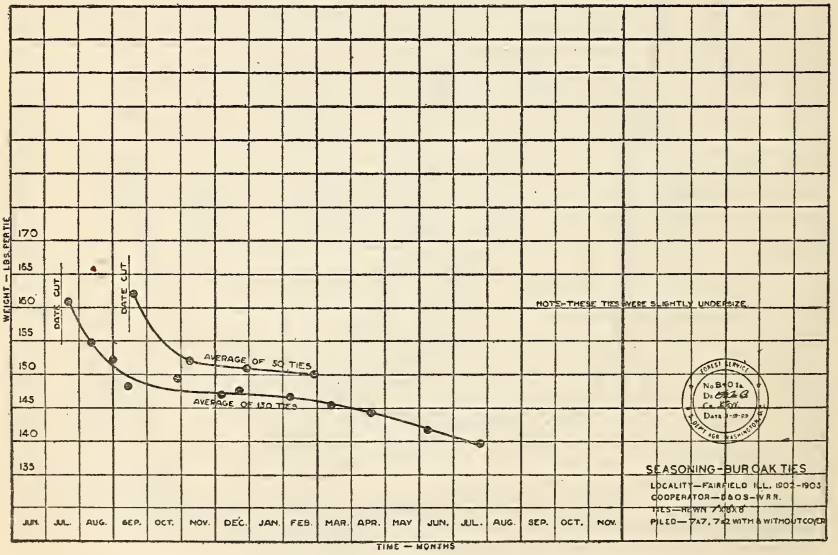

FIG. 11.—Rate of seasoning of bur-oak ties.

moisture from the ties. This is illustrated by the different rates of seasoning at the different times of year. Red gum ties cut in summer lost 75 pounds each in 3½ months, while those cut in the fall lost only 40 pounds in the same length of time. In the case of denser woods like the oaks this difference is less pronounced. Red gum ties cut in Tennessee in summer lost 26 pounds in 4½ months, while those cut in winter and seasoned for the same length of time lost 22 pounds per tie. The retarding effect of winter upon the drying of partially seasoned ties is illustrated in figures 7, 9, 10, 11, and 13. In this case it was so pronounced as to cause the ties actually to gain

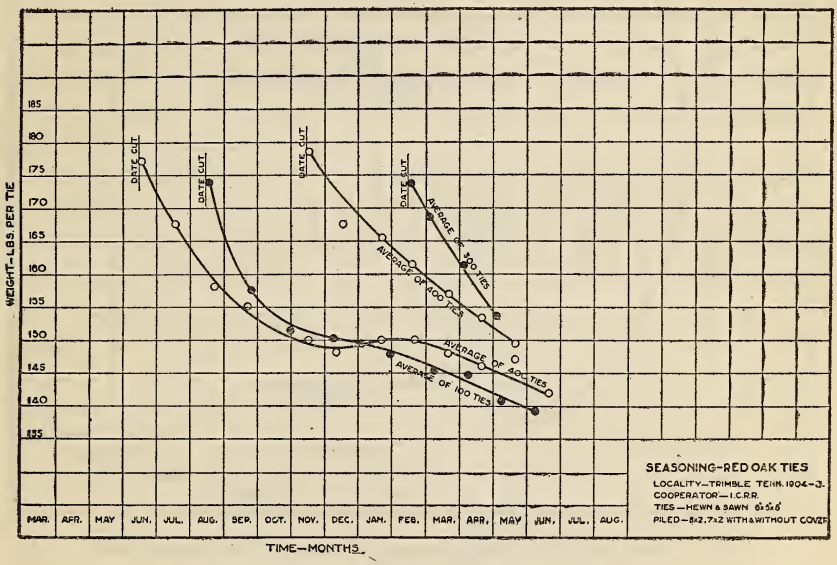

FIG. 12.—Rate of seasoning of red-oak ties.

weight. Douglas fir ties seasoned during six spring and summer months contained 7 pounds less water per tie at the end of that period than after seasoning for three months longer. Because of the more rapid drying when the air is warm, summer-cut ties should have less circulation of air than those cut in winter. Coniferous woods can be given a much freer circulation than hardwoods, but too close piling will almost invariably bring about decay.

The effect of the locality where ties are seasoned can not be overlooked. In the South, where the climate is warm and damp, ties should be given as free a circulation of air as possible. Furthermore, the yard should not be overstocked, as that would start decay. The entire yard should be well drained, free from weeds and decayed wood, and, if possible, covered with cinders.

Method of piling.—Different kinds of wood and climate require different methods of piling. The closer the ties are piled the slower will be their loss in weight. In no case should more than two ties in a pile come in contact with the ground. The most open form is the triangular one, which can be rapidly made and is well adapted for use along the right of way. It should not, however, be used for hardwoods cut in summer, since these will check badly. Good forms of piles are the 7 by 2, 7 by 1, and 8 by 1. These are well adapted for softwoods and most hardwoods cut in summer. They

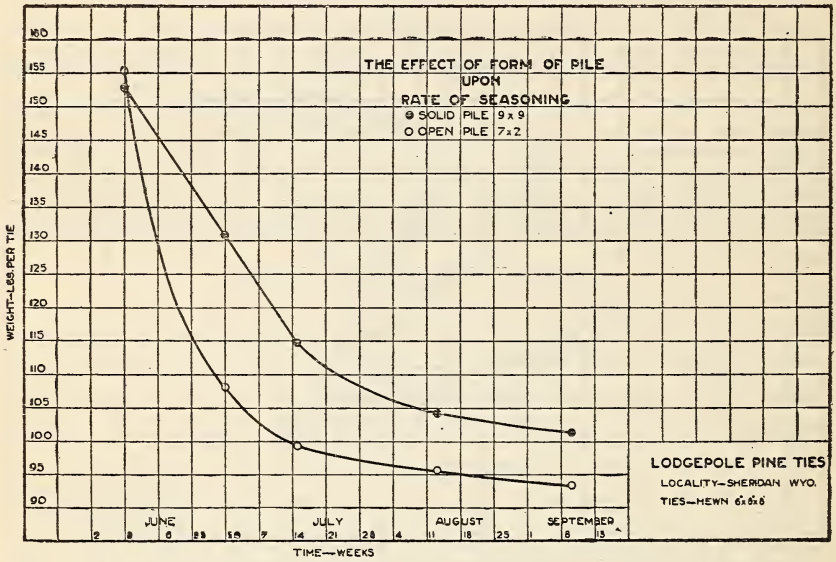

FIG. 13.—Effect of the form of piling upon the rate of seasoning of lodgepole-pine ties.

are easy to build and permit of free circulation of air. When it is desired somewhat to retard the rate of drying, the 8 by 2 or the 10 by 1 form should be used, or if these are still too open, the 7 by 7 form. An advantage of the 7 by 1, 8 by 1, 10 by 1, and similar forms is that no tie lies flat on another, thus giving an easy run-off for rain water and a free circulation of air. In practically no case should untreated ties be piled solidly 9 by 9, since such forms are exceedingly inefficient in regard to seasoning and invite decay. The effect of the form of piling upon the rate of seasoning is shown in figure 13.[1]

Though the Forest Service has made many tests to determine the effect of different forms of roofs on the seasoning of ties, the data

[1] Data from which these curves are drawn were taken from Forest Service Bulletin 41.

secured are not conclusive. However, a slanting roof of ties is fairly efficient in shedding water, and when not requiring too much additional labor can be employed advantageously.

STEAM SEASONING.

Seasoning by steam is not as common to-day as it was a decade ago. Perhaps the chief reason for this is the better knowledge that now exists as to the causes of decay and the effect of steaming on the strength of wood. Pioneers in wood preservation held that to prevent rot it was necessary to coagulate the albumen in the wood, and that steaming did this. Later investigation has shown that the amount of albumen in wood is inappreciable. Moreover, the poor heat conductivity of ties makes it necessary to subject them to a steam bath for at least 4 to 8 hours before the interior temperature reaches that of the outside. This means, of course, a large consumption of steam.

Steaming does not, as then believed, dry out the sap and moisture of the ties and render them thoroughly dry. On the contrary, it increases their moisture content. This may hold true for green as well as air-seasoned ties, as shown in Table 1.

TABLE 1.—*Increase in weight of loblolly-pine ties due to steaming.*[1]

Conditions of steaming.		Gain in weight per tie, due to steaming.	
Period.	Pressures per square inch.	Green ties.	Air-seasoned ties.
Hours.	*Pounds.*	*Pounds.*	*Pounds.*
4	10	2.13	5.1
4	20	.....	6.9
4	30	.62	6.3
4	40	1.12	8.1
4	50	.62	4.3
6	20	.....	10.8
10	20	1.00	10.7

[1] From Tables 10 and 11, Forest Service Circular 39, "Experiments on the Strength of Treated Timber," by W. Kendrick Hatt.

In order to decrease the weight of ties a final vacuum must be drawn. This lowers the boiling point of the water in the wood, causing it to evaporate quickly.

If the steam pressures used are too high, or of too long duration, or if the evaporation of the water from the wood is too rapid, serious decrease in strength will result. This is illustrated in Tables 2 and 3.

TABLE 2.—*Effect of steaming and preservative treatments on the strength of green loblolly pine.*

[Specimens, 2 by 2 inches; tested immediately after treatment.]

Treatment.	Cylinder conditions.			Strength (untreated wood=100 per cent).				Rings per inch.[1]		Moisture.[1]		Specific gravity (dry).[1]	
	Steaming.			Static.		Impact.							
	Period.	Pressure per square inch.	Temperature.	Bending—Modulus of rupture.	Compression parallel to grain.	Bending—Height of drop causing complete failure.	Average of the three strengths.	Control.	Treated.	Control.	Treated.	Control.	Treated.
	Hrs.	*Lbs.*	*°F.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*			*P. ct.*	*P. ct.*		
Steam, at various pressures.	4	.....	[2] 230	91.3	79.1	96.4	88.9	7.0	7.5	60.8	49.2	0.490	0.500
	4	10	238	78.2	93.7	93.3	88.4	6.0	5.0	52.2	37.6	.489	.468
	4	20	253	83.3	84.2	91.4	86.3	7.0	8.0	32.6	34.3	.518	.513
	4	30	269	80.4	78.4	89.8	82.9	7.0	6.5	39.8	48.1	.493	.479
	4	40	283	78.1	74.4	74.0	75.5	7.0	7.0	40.5	42.5	.519	.509
	4	50	292	75.8	71.5	63.9	70.4	7.0	7.0	41.8	46.2	.531	.508
	4	100	337	41.4	65.0	55.2	53.9	6.5	7.0	52.3	45.5	.501	.456
Steam, for various periods.	1	20	257	100.6	98.6	86.7	95.3	6.0	6.5	31.7	39.1	.484	.489
	2	20	267	88.4	93.0	107.0	96.1	5.5	5.0	54.5	55.9	.474	.490
	3	20	260	90.0	93.6	84.1	89.2	7.0	6.0	37.1	33.8	.532	.531
	4	20	253	83.3	84.2	91.4	86.3	7.0	8.0	32.6	34.3	.518	.513
	5	20	253	85.0	78.1	84.2	82.4	6.0	6.5	38.2	39.3	.506	.509
	6	20	242	95.2	89.8	76.0	87.0	5.0	6.0	58.9	36.5	.453	.505
	10	20	255	73.7	82.0	76.0	77.2	6.0	7.0	48.0	47.9	.523	.516
	20	20	258	67.5	65.0	99.0	77.2	7.0	7.0	61.9	52.8	.523	.508

[1] Obtained from specimens used in static bending tests.

[2] It will be noted that the temperature was 230°. This is the maximum temperature by the maximum-temperature recording thermometer, and is due to the handling of the exhaust valve. The average temperature was that of exhaust steam.

TABLE 3.—*Effect of steaming and preservative treatments on the strength of seasoned loblolly pine.*[1]

[Specimens, full-sized ties; seasoned, treated, and reseasoned before tests.]

Treatment.	Cylinder conditions.			Strength (static) (untreated wood=100 per cent).				Rings per inch.	Weight, air-seasoned, per cubic foot.
	Steaming.			Bending.	Compression.				
	Period.	Pressure, per square inch.	Temperature, per square inch.	Modulus of rupture.	Parallel to grain.	At right angles to grain.	Average of the three strengths.		
	Hours.	*Lbs.*	*°F.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Pounds.*
Steam, at various pressures.	4	10	237	99.2	79.3	91.1	89.9	4.9	38.0
	4	20	258	93.7	78.4	99.1	90.4	5.2	37.3
	4	30	274	87.8	83.4	92.7	88.0	5.3	37.9
	4	40	286	88.4	78.1	74.6	80.4	5.2	37.8
	4	50	295	69.1	60.6	74.4	68.0	4.8	36.1
Steam, for various periods.	2	20	257	82.4	81.9	87.1	83.8	5.1	38.1
	4	20	258	93.7	78.4	99.1	90.4	5.2	37.3
	6	20	256	87.5	78.8	92.0	86.1	4.6	36.7
	10	20	256	77.0	75.5	73.2	75.2	4.8	36.7

From Forest Service Circular 39.

It will be seen that the average strength of the green wood greatly decreases with the increase in steam pressures from 88.9 per cent of the natural strength after steaming for 4 hours at about atmospheric pressure, to only 53 per cent when steamed for the same length of time at a pressure of 100 pounds. The same effects were observed when the pressure was kept constant and the length of the steaming period increased. Thus, wood steamed at 20 pounds for 1 hour was 95.3 per cent as strong as that unsteamed, or when steamed at the same pressure for 20 hours was only 77.2 per cent as strong. Similar results were secured with air-seasoned material. Steaming undoubtedly carries with it a danger of injury to the wood, but when some quick artificial means of seasoning ties must be used, steaming at low pressures not to exceed 30 pounds, followed by a vacuum of 25 to 26 inches, may be employed.

OIL SEASONING.

While steam seasoning increases the weight of ties and necessitates the drawing of a vacuum to get the sap and water out of them, seasoning in oil produces the opposite effect, since the ties constantly lose moisture while in the hot bath, and no vacuum is required. Test made on 2-inch by 2-inch by 24-inch specimens showed that this method of drying is likely to cause internal checking. This is illustrated by the specimen shown in Plate II, figure 1. Similar results were secured in drying 8-inch by 16-inch by 16-foot Douglas fir stringers. It is likely that the greater the moisture content of the ties boiled in oil, the greater will be the decrease in strength. Ties partially air seasoned, therefore, will check less during treatment than those thoroughly green.

IMMERSION IN WATER.

After freshly cut ties are immersed in water more or less of their sap will be leached out and the cell walls left in a more porous condition. It might be expected that such ties after removal from the water would season faster than those not soaked, and that they would absorb more preservative when treated. Of a number of hemlock ties tested at Escanaba, Mich., some were soaked in water for various periods.[1] These absorbed considerable water and when piled to season at first lost weight faster than the ties not soaked, but ultimately failed to reach a lower weight per cubic foot. However, when treated with chloride of zinc they absorbed slightly more (0.6 per cent) of the solution than the unsoaked ties. This difference is so slight that soaking ties in water simply to increase their absorption of preservatives is not recommended, unless it can be done without extra expense.

[1] Forest Service Circular 132.

GROUPING TIES TO SECURE UNIFORM TREATMENT.

The importance of properly grouping ties before placing them in the treating cylinder can not be overemphasized. If ties offering unequal resistance to penetration are treated at the same time, those offering the greatest resistance will take practically no preservative, while the others will get it all. Consequently, if ties so treated are placed in a roadbed, the ones heavily injected will outlast the others and the wear on the track will not be uniform. Furthermore, when the ties inadequately treated decay, the load which should be borne by them will be transferred to the sound ones, hastening their mechanical destruction. Thus much of the preservative will be wasted, since there is no economy in preserving ties from decay after they have been worn out. The aim, therefore, should be to have the ties depreciate uniformly, and this can largely be brought about by grouping them in such a manner that they will receive equal amounts of the preservative uniformly diffused. Many tie plants already realize the importance of grouping, and consider the added expense more than justified by the results secured.

The chief factors which determine the ease with which wood may be impregnated are (1) the species of wood, (2) per cent of sap and heartwood, (3) moisture content. The less important are conditions under which seasoned, time of cutting, conditions of growth, and the character of the treatment. The characteristics of wood structure which apparently exert a marked influence on the absorption of preservative are (1) the "pores" or vessels, (2) tyloses, (3) resin ducts and cells, and (4) the composition and density of the cell wall.

SPECIES.

Pores or vessels are characteristic of hardwoods, and do not occur in any of the conifers. They may be likened to pipes running through the wood, furnishing the channels by which food can readily be transported. It is customary to group hardwoods, according to the distribution of these pores, into two classes: (*a*) diffuse-porous woods, like beech, gum, etc., in which the vessels are scattered throughout the annual ring (Pl. III, fig. 1), and (*b*) ring-porous woods, like oak and ash, in which they are confined to concentric rings (Pl. III, figs. 2 and 3). When these vessels are open, it is through them that the preservative first gains entrance into the wood. In red oak, for example, it is possible to blow through 3 or 4 feet of wood and to drive a preservative this distance in one or two minutes. Such woods are as a rule easy to inject, but the preservative is very prone to confine itself to the vessels, leaving layers of untreated wood in between. When the vessels are scattered through the wood, the preservative is much more evenly diffused.

FIG. 1.—INTERNAL CHECKING IN BLACK OAK DUE TO BOILING IN CREOSOTE.

[The two rows of blocks on the left were steamed for four hours at 60-pounds pressure, temperature 153° C. These blocks checked on the outside. The two rows on the right were heated in an open tank for four hours in creosote at 153° C., an unusually severe treatment, resulting in serious internal checking.]

FIG. 2.—WASTE IN HEWING LOBLOLLY PINE TIES.

[Note slab left on stump to save labor of cutting.]

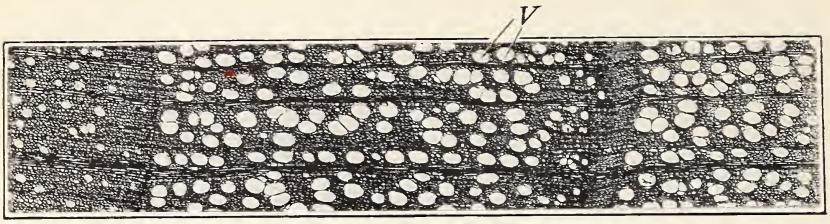

FIG. 1.—CROSS SECTION OF BEECH, A DIFFUSE-POROUS WOOD.

[Note how the vessels are scattered entirely through the annual ring. (V=vessels).]

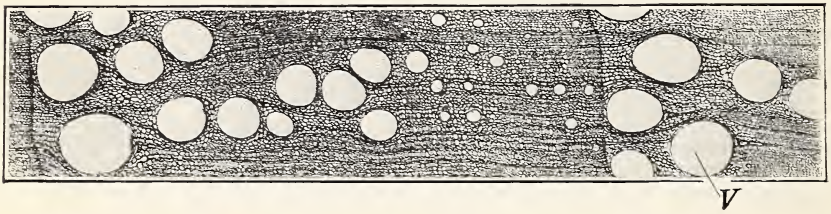

FIG. 2.—CROSS SECTION OF RED OAK, A RING-POROUS WOOD.

[Note how the vessels are confined to the springwood, and are entirely open. (V=vessel).]

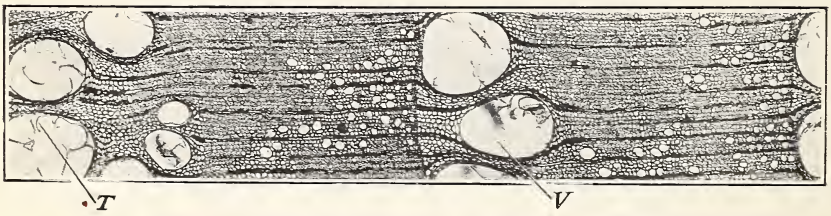

FIG. 3.—CROSS SECTION OF WHITE OAK, A WOOD SIMILAR TO FIGURE 2, EXCEPT THAT THE VESSELS ARE CLOGGED BY TYLOSES.

(V=vessel; T=tyloses.)

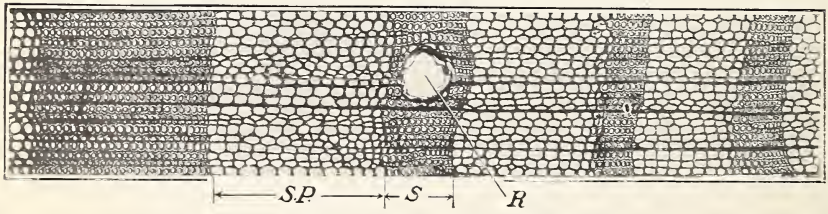

FIG. 4.—CROSS SECTION OF LONGLEAF PINE.

[Note absence of vessels but presence of resin ducts. Note also difference in the thickness of the cell walls in the spring and summer wood. (R=resin duct. S=summerwood. SP=springwood).]

Often these vessels are closed by ingrowths of wood substance called "tyloses," and when this occurs it is exceedingly difficult and often impossible to secure a satisfactory penetration. The marked resistance of white oak to treatment is in all probability due to the clogging of its pores by these tyloses (Pl. III, fig. 3).

The resin ducts of the conifers may be likened to the vessels of the hardwoods in that they furnish easy channels of entrance for the preservative (Pl. III, fig. 4). Some conifers do not possess resin ducts, or, like the spruce, may have them only imperfectly developed. In such cases they may be very difficult to impregnate. The distribution of the resin ducts in the wood also affects the diffusion of the preservative. In some conifers, like longleaf pine, they occur mostly in the summerwood; in others, like the redwood, they are found largely in the springwood. Their presence accounts for the streaky penetration in some creosoted ties, the summerwood appearing as dark bands heavily creosoted and the springwood as light bands containing little or no oil. When the tree is of slow growth these bands are not so apparent, because the annual rings are narrow and the resin ducts are consequently closer together. It seems very probable that the character of the resin in the ducts exerts a strong influence on the ability of the wood to absorb preservative. When the resin is solid, as is often the case in the heartwood of old trees, it plugs the resin ducts so that the preservative can not gain ready entrace. In this respect it exerts an influence analogous to that produced by tyloses, but when the ducts are only partially closed, or the resin is soft or soluble, the resistance to impregnation is much less. Thus it frequently happens that ties cut from young trees or from the younger wood in old trees are more susceptible to treatment than those cut from old wood. When the resin passages are abundant in the pith rays of the wood the ties treat easily in a radial direction, but little or not at all tangentially; consequently, if a thin strip of bark adheres to such a tie it may act as a plug to the radial resin passages which it covers and so prevent penetration at that point. This is shown in Plate I, figure 2, and is characteristic of many pines. Such ties should be carefully peeled before treatment. The composition and density of the cell walls also exert a direct influence on the absorption of the preservative, although this action is not well understood.

Tests made by the Forest Service[1] indicate that the cell walls check when dried below their saturation point, and that these checks lessen the resistance to impregnation. The degree of cell checking or slitting may depend upon the thickness of the cell wall, being greatest in thick-walled cells and least in thin-walled cells. Should

[1] "The Physical Structure of Wood in Relation to its Penetrability by Preservative Fluids," by H. D. Tiemann; published in Vol. II, Part II, Proceedings of the A. R. E. and M. of W. Assn., 1910.

further experiment prove this to be the case, it will aid in explaining why certain ties whose cells are thin-walled and hence light, with a large part of their volume air space, treat with greater difficulty than ties whose cell walls are thick and hence heavy, and which possess little air space. Plate III, figure 4, shows clearly the difference in the thickness of the cell walls in the springwood and summerwood of longleaf pine.

Interesting experiments on 20,000 ties to ascertain the absorptive properties were made by Mr. F. J. Angier in 1908–9 at the treating plant of the Chicago, Burlington & Quincy Railroad, using the zinc-creosote process. The results are summarized in Table 4.

TABLE 4.—*Absorption of preservative by various species of crossties.*[1]

Kind of wood.	Number ties used in the tests.	Absorption per cent of volume.	Number months seasoned in yard.
CLASS A.			
Beech	2,481	21.8	15
Oak, red	3,112	20.9	6–15
Hemlock	1,364	20.7	8–15
Oak, pin	671	19.5	10
Hickory	414	18.8	2– 8
Tamarack	2,329	17.1	6– 8
Oak, white	731	14.2	7
CLASS B.			
Hard maple	691	28.3	15
Poplar	1,348	26.8	7– 9
Sycamore	364	26.6	7
Ash	318	23.0	2– 6
Sweet gum	928	23.0	5– 9
Chestnut	345	22.6	12
CLASS C.			
Shortleaf pine	2,192	36.9	5– 9
White elm	872	36.6	7–15
Cypress, white	662	35.4	7– 8
Red elm	626	34.9	6– 9
Soft maple	599	33.1	6
Red birch	775	33.0	6– 9
Tupelo gum	790	30.7	8

[1] Proceedings of Wood Preservers' Assn., 1911.

Class A includes ties absorbing less than 22 per cent of their volume; Class B, ties absorbing between 23 and 30 per cent; Class C, ties absorbing more than 30 per cent. In all cases the ties were kept in the cylinder until no more preservative could be forced into them. With hardwoods, such as oak, hickory, ash, beech, etc., the pressure was 175 pounds, but with softwoods this was reduced to from 125 to 150 pounds per square inch. In both cases the pressure was held for from two to five hours. No separation of the ties was made on the basis of their proportion of sapwood and heartwood, but about 75 per cent of them were hewed.

PROPORTION OF SAPWOOD.

The sapwood of practically all woods native to the United States readily absorbs preservatives. The heartwood, however, is much more resistant, so much so in some cases that no effective treatment is possible. Two hundred maple ties thoroughly air seasoned (the moisture content ranging from 24 to 39 per cent) were treated by the full-cell and Burnett processes at the Forest Products Laboratory. It was found that of the ties given a full-cell treatment, those containing 43.7 per cent sapwood absorbed 10.48 pounds of creosote per cubic foot, while those containing 82.7 per cent of sapwood absorbed 17.40 pounds per cubic foot. In the Burnett treatments the difference was not so pronounced. Ties containing 46.2 per cent sapwood absorbed 19.7 pounds of solution, while those which contained 80.5 per cent absorbed 22.5 pounds. Because of this difference in the absorption by sapwood and heartwood, ties which contain large amounts of sapwood should be treated separately. Differences in absorption by ties of the same species, but with varying proportions of sapwood, are often greater than in the case of widely different species. If the ties are "pole" ties, viz, cut from small logs ranging in diameter from 12 to 14 inches, it will be found that those of certain species almost invariably fall in the same class when graded with reference to the per cent of sapwood. The grouping will be approximately as shown in Table 5.

TABLE 5.—*Classification of pole ties based on their sapwood content.*

Group I. Sapwood 1 inch or less in width (less than 20 per cent of volume of tie).	Group II. Sapwood 1 inch to 2½ inches in width (more than 20 per cent, but less than 50 per cent of volume of tie).	Group III. Sapwood over 3 inches wide (more than 50 per cent of volume of tie).
Oaks.	Longleaf pine.	Shortleaf pine.
Douglas fir.	White pine.	Loblolly pine.
Cedar.	Hard maple.	Western yellow pine.
Chestnut.	White elm.	Cypress.
Tamarack.	Red elm.	Lodgepole pine.
Hemlock.		Tupelo gum.
Spruce.		Red gum.
		Sycamore.
		Poplar.
		Soft maple.
		Red birch.
		Hickory.
		Ash.
		Beech.

This grouping does not, however, in all cases accurately represent the relative resistance to penetration of the various species. For example, red oak, because of its porous nature, can readily be penetrated to the center, and thus, in spite of its comparatively small amount of sapwood, would be grouped with ties of a structure resembling the elms. Also, the sapwood of soft maple, hickory, ash, and beech is more resistant to treatment than that of the other species mentioned in Group III.

If ties are cut from logs larger than 12 to 14 inches in diameter, as is usually the case with sawed ties, the percentage of sapwood may range from zero to the maximum shown in the table; hence the grouping of such ties may be different from that given. For example, shortleaf pine ties cut with little or no sapwood would fall in Group II, hard maple without sapwood in Group I. Sapwood can be distinguished from heartwood by its difference in color, and it is as a rule easy to separate ties into groups according to their sapwood content. Such a separation will undoubtedly assist in a proper grouping of ties for treatment; but before this grouping can definitely be decided upon as the best, considerably more experimenting will be necessary.

MOISTURE CONTENT.

When ties are green the cell walls and many of the cell spaces are filled with water. To properly inject a preservative this water must be removed, and the extent to which it has been removed governs the amount of preservative which can be injected. It is important, therefore, that all of the ties to be treated at one time should have approximately the same moisture content. The most practical way of insuring this is to pile the ties in the yard and thoroughly air-season them. Some idea as to the length of time ties should be air-seasoned is given in figures 2 to 12.

The conditions under which ties season affect the uniformity of the treatment. Ties seasoned too rapidly are likely to "caseharden," which makes them more difficult to impregnate and affects their strength. Moreover, whether ties are seasoned with the bark on or off affects the treatment. It is good practice to season all ties to be treated in one charge under the same conditions.

CUTTING SEASON.

The time of year the ties are cut also affects the uniformity and degree of treatment. Several tramloads of hemlock ties cut in the summer, fall, and winter were first air-seasoned and then treated with zinc chloride, with the results shown in Table 6.[1]

TABLE 6.—*Effect of the season of cutting on the absorption of preservative.*

Season of cutting.	Weight per cubic foot before treatment.	Average absorption of solution per cubic foot.
	Pounds.	*Pounds.*
Summer	33.4	12.9
Fall	36.2	10.0
Winter	37.3	8.9

[1] Forest Service Circular 132.

It is probably safe to say that, aside from moisture content and case-hardening, the effect of the time of cutting on the penetration and absorption of preservative can be neglected in commercial work. Good practice consists in cutting all ties in winter or late fall whenever possible.

CONDITIONS OF GROWTH.

The arrangement of the cells in the same species of wood grown under different conditions may differ to such an extent as to cause variability in the results of the treatment. When that is the case, the ties should be grouped separately. For example, a plant receiving red oak ties from the South may find it advantageous to group them separately from those received from the North. Moreover, ties cut from various parts of the tree treat differently. No practical way of separating such ties is apparent, except perhaps on the basis of sapwood and heartwood content.

LENGTH OF TIME IN PRESERVATIVE.

In some treating plants the time required to fill the cylinder with the preservative and empty it amounts to an hour or more. This means that the ties on the bottom of the trucks are just that much longer in the preservative than those on top, and hence absorb a larger amount of it. The most practical means of overcoming this objection is to provide for a rapid filling and emptying of the cylinder, or, if this can not be done, to pile the ties most resistant to treatment on the bottom of the trucks.

PRESERVATIVE PROCESSES.

A description of the various methods used in preserving crossties from decay can be found in Forest Service Bulletin 78.[1] A brief synopsis of the various processes, however, is given in Table 7. No attempt has been made to give the various degrees of vacuum, amounts of pressure, temperatures, or time of treatment in the different processes, as these vary at each plant according to the opinion of the treating engineer. It is customary, however, when a vacuum is used, to have the gauge record from 22 to 26 inches for 1 to 3 hours. In steaming the ties the pressures range from about 20 to 40 pounds per square inch, the duration of the steam bath varying from about 1 to 24 hours. The length of time pressure is appplied to the preservative varies from about 1 to 12 hours and the amount of pressure from 100 to 200 pounds per square inch. The final absorptions as given refer specifically to tie treatments, and these usually vary within the limits shown. In treating piling it is customary to specify heavier injections than those mentioned.

[1] "Wood Preservation in the United States," by W. F. Sherfesee.

It will be seen from the table that a wide difference at present exists in the manner of injecting preservatives into ties, especially in regard to their preparation for receiving the preservative.

In the full-cell, Card, and Allardyce processes, if the final vacuum is drawn, it is used simply to dry the ties. In the Rüeping and Lowry processes the final vacuum is drawn to remove some of the oil which has been injected into the wood, constituting what is commonly known as an "empty-cell" treatment.

TREATING-PLANT OPERATION.

AIM OF TREATING OPERATION.

UNIFORM TREATMENT FOR ALL TIES.

One of the two essentials in treating-plant operation is to secure a uniform treatment for all ties. How this can best be done is described on pages 20 to 22. Unless the ties are properly selected, particularly on the basis of moisture content, species, and per cent of sapwood, it is useless to look for good results. The proper grouping of ties on the cylinder buggies is the first step upon which all other steps depend.

TABLE 7.—*Synopsis of wood-preserving processes used in the treatment of ties.*

Process.	Condition of ties when treated.	Preservative used.	Treatment in cylinder.			Approximate final absorption of preservative per cubic foot (pounds).
			Preliminary.	Injection.	Final.	
Full cell	Seasoned or green.	Creosote	Steam and vacuum [1]	Pressure applied to preservative.	None [2]	8–12.
Burnett	do	$ZnCl_2$	do		do	0.25–0.5.
Boiling	do	Creosote	Heating in oil		do	8–12.
Buehler	Seasoned	do	Vacuum		Air pressure.	8–12.
Do	Green	do	Heating in oil		do	8–12.
A. C. W.	Seasoned or green.	do	Steam, vacuum, and air pressure.		do	8–12.
Rüeping	Seasoned	do	Air pressure		Vacuum	4–7.
Lowry	do	do	None		do	8+.
Card	Seasoned or green.	Creosote and $ZnCl_2$.	Steam and vacuum [1].		None [2]	0.5 $ZnCl_2$, 3–4 creosote.[3]
Allardyce	do	do	do		do	Do.
Wellhouse	do	$ZnCl_2$, glue, tannin.	do		do	0.5 $ZnCl_2$.

[1] Steaming sometimes omitted when ties are air-seasoned.
[2] Final vacuum sometimes used to dry the ties.
[3] $ZnCl_2$=zinc chloride.

NOTE.—Some engineers say that they disfavor the treating of green timber by the Burnett, Card, or Wellhouse processes.

DIFFUSION OF PRESERVATIVE.

The second essential result to be obtained by a treating plant is thorough diffusion of the preservative into the individual tie. The preservative should be injected as deeply into the tie as possible. A simple but effective rule is to insist upon the complete penetration of all sapwood. With certain kinds of ties, such as loblolly pine and black gum, which usually contain a large proportion of sapwood, this means that they should either be treated with zinc chloride, or with

creosote by the empty-cell process. If treated with creosote by the full-cell process with the quantity of oil usually prescribed, the preservative is likely to be confined to the outer layers of the wood, leaving the interior unprotected. When zinc chloride is used as preservative for such ties it should be mixed in a weak solution of about 2 or 2½ per cent and thoroughly diffused through the tie, rather than used in a concentration of 5 or 6 per cent and injected only in the outer layers of the wood. A simple means of determining the diffusion of creosote is to bore into the tie. On account of the variation in different parts of the timber, however, it is not always a true guide. With zinc chloride solutions the problem of determining the penetration is much more difficult. A good way is to select a tie which has absorbed an average quantity of preservative, saw it in two, and moisten its surface with a 1 per cent solution of potassium ferrocyanide. After it has dried for a few minutes, again moisten the surface with a 1 per cent solution of uranium acetate. Soon the untreated wood will turn a deep maroon color, while that impregnated with zinc chloride will be slightly whiter than the natural color. A more accurate method is to analyze borings for zinc, but this is a laborious operation, and must be performed by a trained chemist.

Too little attention is paid to securing a proper penetration of the preservative. Many specifications omit any mention of it, requiring only that the absorption shall be a certain amount. When the penetration is specified the terms are often impracticable. For example, it is sometimes specified that "the preservatives shall completely saturate all the wood fibers," or it shall be "not less than 1 inch at any point," both of which may be impracticable. It is possible in all cases, however, to insist upon a complete penetration of the sapwood, and of as much of the heartwood as conditions of the particular treatment will permit.

FEATURES AFFECTING TREATMENT.

The various manipulations of the plant during the treating process affect the distribution of the preservative in the ties. The more common manipulations, such as the preliminary vacuum, the rate of applying pressure to the preservative, and the final vacuum, are under investigation at the Forest Products Laboratory. The following discussion is based upon results obtained from these investigations and upon observations at commercial plants:

PRELIMINARY VACUUM.

A preliminary vacuum drawn in the treating cylinder decreases the resistance to the entrance of the preservative into the ties, and so enables the operator to secure the desired absorption in a shorter time than otherwise. With light injections the absorption in ties so

treated will tend to vary more than when no preliminary vacuum is used. Ties offering least resistance may take most of the preservative, while those most resistant may get very little of it.

Fifty-four pieces of loblolly pine about 8 inches in diameter and 25 inches long were treated with creosote at the Forest Products Laboratory by the full-cell process. All were treated exactly alike, except that about half were given a preliminary vacuum of 26 inches for 15 minutes, while the others were treated without a vacuum. To secure an absorption of 18 pounds per cubic foot it was necessary, when no preliminary vacuum was used, to hold the pressure at 50 pounds per square inch for from one-half to one hour. With the preliminary vacuum this was reduced to five minutes. The varia-

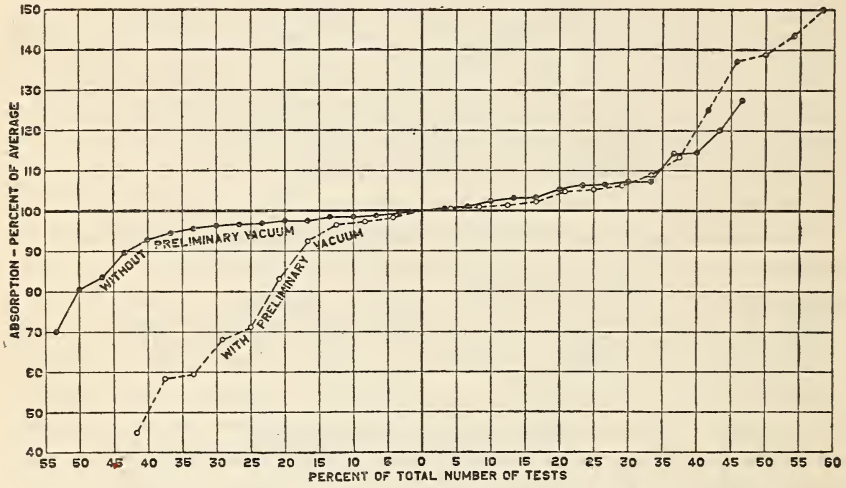

FIG. 14—Effect of preliminary vacuum on the absorption of creosote by loblolly pine.

tions of the individual pieces from the average absorption are shown in figure 14. It is seen that with a preliminary vacuum the absorption varied over 50 per cent above and below the average, and that only 50 per cent of the pieces were within 10 per cent of the average absorption. With no preliminary vacuum the absorption varied only 30 per cent from the average, and 73 per cent of the specimens were within 10 per cent of it. This difference in absorption disappears as the length of the pressure period on the preservative increases. It is apparent, therefore, that the initial vacuum can be omitted to advantage in light treatments in which only a small amount of preservative is forced into the wood. In heavy injections, where the ties are treated to refusal, the tendency of the preliminary vacuum to produce erratic absorption is not so pronounced, and its use will be found of considerable assistance.

RATE OF APPLYING PRESSURE.

Most tie-treating specifications call for a pressure on the preservative varying from 100 to 175 pounds per square inch until the desired amount has been forced into the wood, but few if any of them specify the rate at which this pressure should be applied. Pressures applied rapidly tend to produce erratic results in absorption similar to those caused by the preliminary vacuum in light treatments. The most uniform distribution is secured by applying the pressure gradually. A good way to do this is to hold the pressure temporarily at 75 pounds per square inch, and increase it in steps of 25 pounds every 15 minutes until the pressure or absorption desired is obtained. Such a procedure may require a longer pressure period, but the results secured in light treatments will fully warrant it.

FINAL VACUUM.

After the ties have been impregnated a common practice is to drain the cylinder and apply a final vacuum. This is done to dry the surface of the ties, and sometimes, in addition, to remove some of the preservative that has been forced into the wood.[1] Unless the ties are permitted to drain in the cylinder for a considerable time, or a final vacuum is drawn, they will continue to drip after being removed. Much oil is thus lost which has been recorded by the gauges as "absorbed" by the ties. It is, therefore, poor practice to remove treated ties from the cylinder until they have stopped dripping freely.

MEASURING THE ABSORPTION.

The preservative treatment of ties looks like a simple operation, but experience has shown it to be quite the contrary. In fact, the difficulties encountered and the opportunity afforded for poor work are reasons why the increase in the use of treated ties is less rapid than it otherwise would be. Measuring the absorption of preservative may be subject to serious error, which, if not provided against, is more than likely to result in an unsatisfactory preservative treatment.

CAUSES OF ERRORS.

Difficulty of measuring volume of charge.—The volume of the ties in the treating cylinder could easily be determined, irrespective of their form, by subtracting the quantity of preservative it takes to fill the cylinder when charged from that necessary to fill it when empty, and deducting the volume of the cars, were it not for the fact that the

[1] It is customary at present to use the final vacuum only with creosote, or at times, when creosote is mixed with zinc chloride. Other preservatives are either not sufficiently valuable to warrant recovery, or as in the case of water solutions the amount of salt injected is controlled by varying the strength of the solution, a maximum quantity of solution being injected.

ties will absorb the preservative while the cylinder is being filled. The amount absorbed varies with the kind and condition of the ties, being greatest in the case of porous woods air-dry and least for resistant woods when green, but generally ranges from about 5 to 20 per cent. Some treating plants allow for this "initial absorption," and deduct 10 per cent from the total amount of preservative to be forced into the ties after pressure is applied.[1] There is no satisfactory way of determining just what this initial absorption will be, and it must be worked out through experience at each plant. The volume of sawed ties, which are uniform in size, can usually be determined with sufficient accuracy by direct calculation.

Expansion of creosote.—Creosote expands considerably when heated, averaging about 1 per cent for every 22½° F. rise in temperature. It is frequently run into the treating cylinder at about 200° F. and its temperature invariably falls from 10° to 60° when it strikes the ties. Unless brought back to its temperature at entrance this contraction may be charged against absorption by the ties. For example, a 45° drop in temperature may produce the same effect on the scale reading as though each tie had actually absorbed from 3 to 5 pounds of oil. Similar errors will be introduced in taking the final reading of absorption when the height of the oil in the measuring tank after the treatment has been completed is subtracted from the height before treatment, unless the temperature at both times is the same. It is important, therefore, to keep the temperature of the oil as nearly constant as possible (with no greater variation than 20° F.); or, if this can not be done, to correct for temperature errors by using the proper coefficients of expansion. For zinc treatments and others of a similar nature such corrections need not be made.

Expansion of the cylinder.—When hot creosote enters the comparatively cool treating cylinder it produces an expansion of the metal which is further augmented by an internal pressure often as high as 175 pounds per square inch. This is taken up by steel rollers or "turtles" between the cylinders and the piers on which it rests. For a cylinder made of ¾-inch boiler steel, 7 feet in diameter and 132 feet in length, this increase in volume may amount to about 18 cubic feet, equivalent to an absorption of about 1,187 pounds of preservative, or 1.48 pounds per tie in a charge of 800 ties.

Compression of the oil and wood.—When pressure is applied to creosote the oil is compressed. At best, however, this can produce only an insignificant error, since creosote under ordinary operative conditions compresses less than one-tenth of 1 per cent. The error due to the compressibility of the ties is also insignificant. Some tests were made at the Forest Products Laboratory in which 20 pieces of

[1] Some treating engineers claim that blowing the preservative out of the treating cylinder into the measuring tank also blows some of the preservative out of the ties, especially if they are porous.

green red oak and black oak, 2 by 2 inches in cross section, were tested in a 100,000-pound machine, the load being applied radially and tangentially. The average modulus of elasticity was 50,375 pounds per square inch. Disregarding the longitudinal dimension, the volumetric compression due to an exterior pressure of 200 pounds per square inch ranged from 0.51 to 1.30 per cent, or an average of 0.80 per cent. This compression is probably much in excess of that which takes place in practice, since when ties are submerged in a preservative fluid the pressure is applied from all directions. Furthermore, at least a part of this pressure is transmitted to the interior. It would seem, therefore, that the decrease in the volume of ties undergoing treatment, due to the pressure exerted on them, can be entirely disregarded.

"Kickback" of preservative.—When pressure is applied to a cylinder charge the oil, wood, and the air confined in the wood are under compression and the cylinder is under tension. If the pressure is released a certain amount of the preservative will be forced out of the cylinder, although it remains constantly full. The amount of preservative thus forced out will be called the "kickback." It varies with many conditions, and unless provided for may result in errors of measurement for absorption of from 10 to 40 per cent. In the treatment of air-seasoned red oak and maple ties at the Forest Products Laboratory by the full-cell process it was necessary, after the desired absorption had been reached, to allow from 20 to 30 per cent for the oil which did not remain in the ties.

To secure data on the variability of the "kickback" a careful series of tests was run on 36 pieces of air-dry longleaf pine. These were cut 2 inches by 4 inches by 4 feet, matched, divided into three groups of 12 each, and treated in three different runs in a cylinder approximately 18 inches in diameter and 4 feet long. In all cases the drip was stopped when it amounted to less than one-half pound of creosote in a half-hour period. The runs were made as follows:

Run 1.—No preliminary or final vacuum was used. The cylinder was filled with creosote in 6 minutes and the oil raised to a temperature of 180° F. A pressure of 120 pounds per square inch was immediately applied and held for 7 minutes. The pressure was then released through the top of the cylinder for 15 minutes, after which the cylinder was drained and the wood permitted to drip for 121 minutes, when it was removed and weighed.

Run 2.—After the wood was placed in the cylinder a preliminary vacuum of 25½ inches was held for 15 minutes, the total vacuum period amounting to 22 minutes. Without breaking the vacuum the creosote was then drawn into the cylinder, the operation consuming 5 minutes. The temperature of the creosote on entering the cylinder dropped to 125° F. It was raised to 181° F. in 12 minutes, when

a pressure of 120 pounds per square inch was immediately applied and held for 3 minutes. The pressure was then released for 16 minutes through the top of the cylinder, after which the cylinder was drained and the wood permitted to drip for 73 minutes, when the charge was removed and weighed.

Run 3.—A preliminary air pressure of 50 pounds per square inch was immediately applied and held for 15 minutes, after which the oil was pumped into the cylinder against this pressure, the operation taking about 10 minutes. The temperature of the oil on entering the cylinder dropped to 156° F. It was then raised to 180° F., consuming 9 minutes. During the heating period the pressure in the cylinder varied between 55 and 70 pounds per square inch. As soon as the oil reached 180° F. a pressure of 120 pounds per square inch was applied and held for 78 minutes. The pressure was then released through the top of the cylinder for 14 minutes, after which the cylinder was drained and the wood permitted to drip for 128 minutes, when the charge was removed and weighed.

The results of these runs are given in Table 7. It will be seen that the "kickback" was least when a preliminary vacuum was drawn, and greatest when the cylinder was first filled with compressed air.[1]

To illustrate the possible source of error through this "kickback" on the release of pressure suppose, for example, it amounts to 20 per cent, and the specifications call for a 10-pound per cubic foot injection. If the "kickback" is disregarded and the pumps kept running until the gauges show an injection of 10 pounds per cubic foot and the pressure is then released, only 8 pounds per cubic foot will be left in the ties. If, on the other hand, the "kickback" is considered, then the pumps will be kept running until the gauges indicate an absorption of 12.5 pounds per cubic foot, which on the release of pressure will leave 10 pounds per cubic foot in the ties. If this "kickback" is released through an underground tank or some measuring tank other than the one used during treatment (and this is a common practice), the chances for error in measuring the absorption are increased.

Expansion of wood.—Another possible source of error in measuring absorption is the expansion of the ties due to raising their temperature. Assuming the thermal coefficient of linear expansion of wood, 0.00001 per degree Centigrade parallel to the fiber and 0.00006 across the fiber[2] and that the ties are raised in temperature 60° C. (140° F.) during their treatment, then the increase of volume in a charge

[1] When the preliminary vacuum was drawn, only 3 minutes of oil pressure were required to force 12.3 pounds of oil per cubic foot into the wood, but when the cylinder and wood were first filled with compressed air it took 78 minutes to force 12 pounds of oil per cubic foot into the wood. That the preliminary vacuum rendered it easier to force the preservative into the wood is therefore apparent. After the run the sticks were split and the penetration in run 3 was found to be slightly greater than in runs 1 and 2. Furthermore, the sticks in run 3 were treated more uniformly than in the other runs, especially run 2, in which the penetration and absorption were very irregular.

[2] Experiments of Glatzel and Villari: Smithsonian physical tables, 5th rev. ed., p. 223.

of 800 ties will be about 22 cubic feet, equivalent to about 1,386 pounds of creosote, or 1.7 pounds per tie. If the ties are raised more than 60° C. in temperature, the volume increase will, of course, be greater.

TABLE 8.—*"Kickback" of creosote on the release of pressure in a treating cylinder.*

Run No.	Pressure period.		Temperature of preservative in treating cylinder.	Maximum amount of preservative forced into wood at end of pressure period per cubic foot.	"Kickback" or amount of preservative forced out of cylinder on release of pressure.			Oil recovered by drip.		Final absorption (oil remaining in wood after "kickback" and drip) per cubic foot.
	Time.	Pressure per square inch.			Amount per cubic foot.	Time.	Maximum absorption.	Amount per cubic foot.	Time.	
	Min.	*Pounds.*	*°F.*	*Pounds.*	*Pounds.*	*Min.*	*Per cent.*	*Pounds.*	*Min.*	*Pounds.*
1	7	120	180–185	12.9	4.80	15	37.0	0.9	121	7.2
2	3	120	180–181	12.3	2.40	16	20.0	.5	73	9.4
3	78	120–130	180–184	12.0	4.50	14	37.5	1.0	128	6.5

Extent of possible errors.—The extent of the various errors possible in measuring absorption may be illustrated by the following example: Assume the treating cylinder to be 7 feet in diameter, 132 feet long, and to hold a charge of 800 7-inch by 9-inch by 8-foot ties; assume also that 10 pounds of creosote per cubic foot are to be injected into and left in the ties; that a pressure of 175 pounds per square inch is used during the treatment; that the oil in the measuring tank is maintained at 200° F. and is injected into the wood at 180° F.; and that the normal temperature of the cylinder and wood is 60° F. With all gauges working perfectly, no leaks of any kind occurring, all air out of the cylinder when the oil pump is started, and the volume of the ties accurately known, the following errors may take place:

	Pound per tie
1. Chargeable to contraction in the volume of creosote	1.85
2. Chargeable to the expansion of the cylinder due to temperature	1.35
3. Chargeable to the "kickback" (assumed to be 20 per cent of the absorption).	7.00
Total positive errors	10.20
4. Chargeable to the expansion of the wood	1.50
Total in excess of apparent absorption	8.7

Thus, out of a total specified injection of 10 pounds per cubic foot, or 35 pounds per tie, 8.7 pounds per tie may be forced into the cylinder, but either will not go into or not remain in the ties, constituting a total error of about 25 per cent. In plants operating with zinc chloride, item 1 may be eliminated and item 3 will be less than that given.

Tank gauges.—Fortunately, these sources of error can be guarded against by pumping the preservative from the cylinder back into the measuring tank from which it came, and applying the temperature correction to the oil. If the preservative is scattered in two or more tanks there is no good way of checking the absorption, but when it is taken from and returned to the same measuring tank in any one treatment, all that is necessary in order to ascertain the actual absorption is to subtract the difference in the height of the float before and after treatment, after applying the temperature correction to the oil at both readings. In all cases where gauge readings are depended upon, the absorption should be determined in this way. *No other method except that of actual weight of the ties before and after injection should be used.* Attention to this simple rule will greatly increase the efficiency of the treatment.

Tank scales.—It is probable that a system of weighing the preservative by having the measuring tank mounted on scales will prove preferable to one employing floats. With the former device no temperature corrections need be made, and errors incident to the use of floats are entirely avoided. Such a scheme has been tested at the Forest Products Laboratory with small-size apparatus and gave thorough satisfaction. Of late this principle has also been put into commercial use.

It has been claimed that if ties only partially seasoned are run into the treating cylinder and impregnated with creosote, the entrance of the creosote will drive out some of the water confined in the wood, and hence a system of measuring the absorption by tank scales would show less absorption than has actually taken place. All the tests made at the Forest Products Laboratory failed to show that any appreciable amount of water was forced out of wood during its treatment, provided the boiling point of water was not exceeded. When the boiling point is exceeded, at atmospheric pressure, the water in the ties will be converted into steam, and will collect in the top of the cylinder, whence it may be drawn off. This condition, however, is peculiar to the so-called "boiling process," and need not be considered in ordinary treatments.

Track scales.—Because of the likelihood of error in the present system of measuring absorption, the suggestion has been made that the track scale (weighing the ties before and after treatment) be substituted for the tank gauge. While this scheme is an excellent one, it will by no means eliminate the present errors. It has already been shown (Table 1) that ties, when steamed, frequently increase rather than decrease in weight. With track scales it would be necessary to run steamed ties out of the cylinder and weigh them before injecting the preservative (which is impracticable), otherwise the increased

weight would be charged to the absorption. Again, if the ties were seasoned in oil as is done in some processes, they might decrease in weight to such an extent that their weight after treatment would be no greater, or even less, than their weight before treatment, although they had absorbed the desired amount of preservative. This is shown by experiments made by the Forest Service in Louisiana. Six absolutely green longleaf pine posts were cut, measured, and weighed, and submerged for six hours in a tank of creosote heated to 230° F. At the end of this period they were removed from the hot oil, and four of them were submerged in a second tank containing creosote at a temperature of 120° F. The two others were weighed immediately after the hot bath. The results are given in Table 9, which shows that the posts weighed on an average only 0.6 pound per cubic foot more after treatment than they did before, although they had received an estimated absorption of 10 pounds of creosote per cubic foot.

TABLE 9.—*Effect on weight of boiling green longleaf pine in creosote.*

Post No.	Weight per cubic foot before treatment.	Weight per cubic foot after hot bath.	Loss per cubic foot of water due to bath in hot oil.	Weight per cubic foot when taken from cold oil.	Absorption of oil per cubic foot.	Penetration.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Inches.*
1	60.6	[2] 50.2	[2] 10.4	56.2	6.0	1¾
2	54.4	[2] 45.1	[2] 9.3	56.3	11.2	2⅞
3	57.2	[2] 47.4	[2] 9.8	57.2	9.8	1⅞
4	50.0	[2] 41.7	[2] 8.3	54.7	13.0	2¼
5	[1] 50.6	43.8	7.8	Control post	.....	.....
6	[1] 50.6	40.9	9.7	.....do.....	.....	.....
Average	55.5	.....	.....	56.1	10.0	2¼

[1] Not included in average. [2] Weight calculated.

Track scales can not be effectively used when the ties are given such a preliminary treatment as steaming, or boiling in oil, which changes their original weight, but they should prove highly effective for those treatments in which the differences in the weight before and after treatment truly represent the actual absorption. This would be the case when the ties are air seasoned before treatment and the preservative is simply forced into them without preliminary treatments of the characters mentioned.

PROTECTION OF TIES FROM MECHANICAL WEAR.

It has been estimated that from 10 to 75 per cent of unprotected ties fail by rail and spike cutting.[1] Since the number of treated ties is increasing annually, this percentage will also increase rapidly unless improved methods of fastening rails are generally adopted. Already the amount of preservative injected into ties is in some cases being

[1] Proceedings A. R. E. and M. of W. Assn., vol. 9, 1908.

reduced because it is claimed to be more than is necessary to prevent decay throughout their mechanical life. With increased mechanical life of the tie the efficiency of the preservative treatment may also be increased.

The most practical means of reducing the mechanical destruction of ties are through the use of tie-plates and improved forms of spikes.

TIE-PLATES.

Tie-plates are designed primarily to (1) Distribute the impact and compression of trains over the tie; and (2) absorb the grinding action of the rail.

If the tie-plate is too light it will soon buckle, or if its bearing surface is too small it will become embedded in the tie. In either case the value of the plate is reduced. It is essential, therefore, to use plates that are strong enough to withstand the pressure exerted on them, and that have sufficient surface area to properly distribute the load. Failure to meet these conditions will almost invariably result in severe mechanical wear on the tie. This is shown in Plate IV, figure 1.

Many forms of tie-plates are now on the market, but in general plates may be divided into two groups: [1] (1) Pronged or ridged plates; (2) flat plates.

In the opinion of some engineers the tie-plate should be so firmly fastened to the tie that it really becomes a part of it. To secure this condition, the bottom of the plate is pronged, ridged, or flanged. Plates of this type were used in test ties on the Northern Pacific and Chicago & Northwestern experimental tracks. Although they have not been in service long enough to show their real worth, the following points were observed during recent inspections. When the plates are heavily ridged, it takes a very heavy load to embed the ridges and bring the plates down flush with the tie. In the Chicago & Northwestern track, even after two years' service, the majority of the ridged plates were elevated about one-fourth inch above the tie. This was due in part to the resistance offered by the ridges to embedment in the wood and in part to sand and gravel which collected under the plate; also, to the fact that the traffic over this portion of the track is now very light. After these plates become firmly embeded they have a tendency to split open the ties, and thus not only weaken them, but furnish catch basins for the retention of rain

[1] Wooden plates have also been used experimetnally, and are being tested by the Forest Service in both the Chicago & Northwestern and Northern Pacific tracks. The plates are made of creosoted oak and maple, about five-eighths of an inch thick, 8 inches long, and as wide as the base of the rail. They were inserted between the tie and the rail without any previous adzing, the common practice abroad. The results thus far have been that the plates split badly, and at times have become loose or displaced. In some cases they have embedded themselves into the ties. This is shown in Plate IV, figure 2. Although the tests with wooden plates have not as yet been completed, the results thus far secured have not been satisfactory. It is thought, however, that this is largely due to the poor manner in which they were placed.

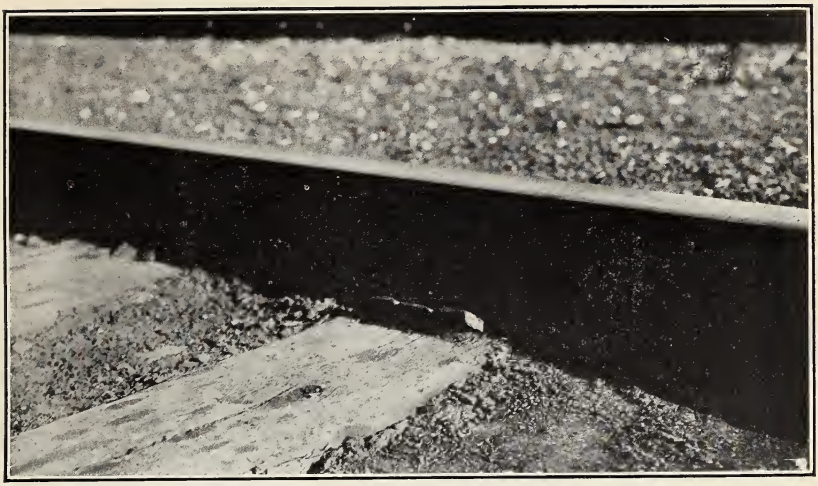

FIG. 1.—RESULT OF USING A SMALL TIE PLATE ON A SOFTWOOD TIE.
[Note buckling of the plate and crushing of the wood fibers.]

FIG. 2.—WOODEN TIE-PLATE CRUSHED INTO A GREEN HEMLOCK TIE AFTER THREE YEARS' SERVICE.

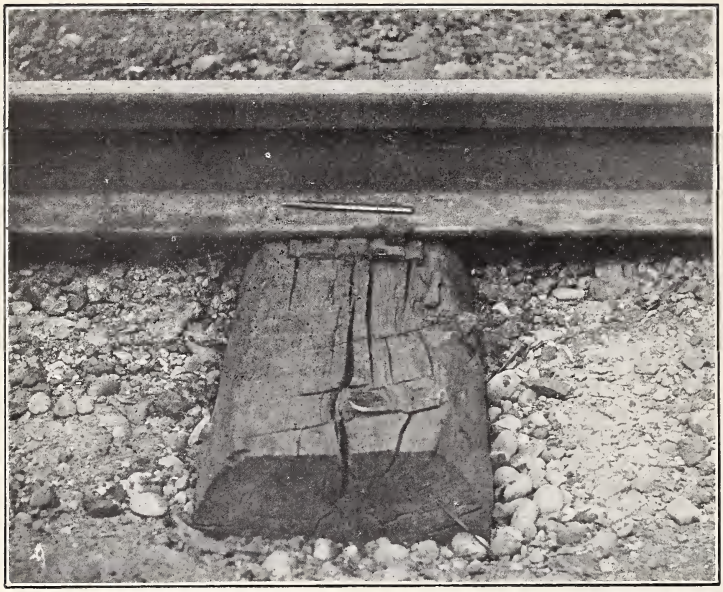

FIG. 1.—TREATED TIE SPLIT BY THE FLANGES OF THE TIE-PLATE, THUS EXPOSING THE UNTREATED INTERIOR TO DECAY.

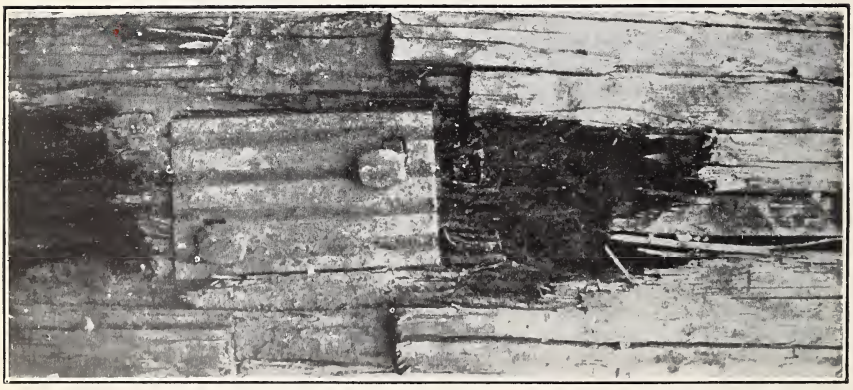

FIG. 2.—LOBLOLLY PINE TIE, TREATED WITH ZINC CHLORIDE, AFTER FOUR YEARS' SERVICE IN TEXAS, SHOWING DESTRUCTION OF WOOD BY TIE-PLATE AND SPIKES.

FIG. 1.—SCREW SPIKE DRIVEN THROUGH A TIE-PLATE WITHOUT REENFORCING SHOULDER.

[Note how the spike is bent by the lateral thrust of the rail after three years' service.]

FIG. 2.—FLAT-IRON PLATE WITH SHOULDER FOR REENFORCING HEADS OF SCREW SPIKES.

[Used in Chicago, Milwaukee, and St. Paul test track. Only two spikes were driven through each plate, as they were deemed of sufficient strength.]

water. In ties which are difficult to impregnate with preservatives these checks may extend beyond the zone of treated wood and thus expose the untreated interior of the tie to decay. (Pl. V, fig. 1.) Another characteristic of such plates is to grind into the wood fibers, especially of softwood ties such as loblolly pine, cedar, etc. This action also may extend beyond the treated portions of the tie and cause interior rot. (Pl. V, fig. 2.) These features are unquestionably objectionable, and in some cases may prove of such a serious nature that they will overbalance the good points, such as adherence to the tie and lack of rattling, claimed for plates of this type.

The objectionable features of pronged or flanged plates are obviated if they are made flat and so rest flush on the surface of the tie. The chief objections to this type seem to be the rattling noise which they make when they are not firmly held by the spikes, and the fact that all resistance to creeping and lateral thrust must be borne entirely by the spikes. The rattling, however, would seem to be an excellent indication that the spikes are loose and need attention. Just how much weight must be attached to the second objection can not at this time be ascertained from the plates under observation by the Forest Service. Thus far no creeping or widening of the gauge of the experimental track has been noticed.

It seems, moreover, in view of the data thus far secured, that, of the various forms of tie-plates now under tests, those made of metal with a flat bearing surface, or with the bearing surface only slightly ridged, are giving better service in protecting the ties from mechanical destruction than those made of metal heavily flanged or pronged.

A feature which is not at present taken into account, but which unquestionably will be, is the size of tie-plate to be used on different kinds of wood. A softwood tie like loblolly pine is more subject to rail cutting than a hardwood tie like oak, and consequently needs a larger tie-plate for its protection. Some tests of the compressive strength of various kinds of ties gave the following results:

The average stress under the rail bearing at the elastic limit on natural red-oak ties is 1,131 pounds per square inch; on natural loblolly pine ties, 578 pounds per square inch; on shortleaf pine, 642 pounds; on longleaf pine, 690 pounds; and on red gum, 830 pounds.[1]

In other words, loblolly pine is only half as strong as red oak and consequently needs a plate with a considerably larger area in order properly to distribute the load.

SPIKES.

The practice of spiking ties to the rail has long been recognized as capable of improvement. The spikes, especially in softwood ties, do not hold firmly, and permit the rail to "creep" and "pump," thus greatly shortening the life of the tie. Furthermore, they tear the

[1] Tests made at Purdue University by W. K. Hatt. Proceedings A. R. E. and M. of W. Assn., Vol. II, part 2, p. 844, 1910.

wood fibers, work loose, and permit rain to collect and decay to start. This necessitates a rather frequent respiking of the rail, which often fills the tie with holes to such an extent that it is "spiked to death" and must be renewed. It was thought that by first boring a hole into the tie and then driving the spike into it, the fibers would not be torn and the spike would hold more firmly. Tests were made [1] in which ordinary $\frac{9}{16}$-inch square spikes were driven into red-oak ties previously bored with holes $\frac{3}{8}$, $\frac{7}{16}$, and 1.2 inches in diameter. Although the spikes were driven by an experienced trackman, in over half the cases they failed to follow the holes. Their resistance to pulling was thus reduced. When no hole was bored the average force required to pull the spikes was 8,827 pounds; when bored in the manner above described the respective forces were 8,050, 8,106, and 7,154 pounds. In order to overcome the objection mentioned the spikes were pointed on four sides, and when this was done there was no difficulty whatever in getting them to follow the holes. Furthermore, their resistance to vertical pull was increased and the wood fibers were not seriously torn. The number of pounds required to pull spikes from red-oak ties was as follows: [2]

	Pounds.
Ordinary $\frac{9}{16}$-inch square spikes driven without boring	7,613
Ordinary $\frac{9}{16}$-inch square spikes pointed on four sides—driven in hole $\frac{3}{8}$ inch in diameter	8,178
Ordinary $\frac{9}{16}$-inch square spike pointed on four sides—driven in hole $\frac{7}{16}$ inch in diameter	7,856
Ordinary $\frac{9}{16}$-inch square spike pointed on four sides—driven in hole $\frac{1}{2}$ inch in diameter	7,664

When the diamond-pointed spikes were driven into the tie without first boring holes, the ties were almost invariably split. It appears, therefore, that they can not be used satisfactorily without previous boring.

Some of the ties used in these tests were treated with creosote, others with zinc chloride, and still others were left untreated, but no appreciable difference due to treatment was noticed. In a few cases a heavy oil was poured into the holes and allowed to soak for 16 hours before the spikes were driven. The resistance to pull was decreased from 7,644 to 6,628 pounds. While no tests were made, it is quite possible that if the holes are bored into the ties before they are treated the resistance of the spike will be less than if they are bored after treating. In spite of this, however, it is believed that if holes are bored at all they should be bored before and not after treatment, since in the former case the ties will be fully protected against rot.

[1] Report (unpublished) on "Spikes Driven into Bored Holes," by J. A. Newlin, in charge of timber tests, Forest Products Laboratory.

[2] It will be noticed that the spikes driven in the first test held more firmly than those driven in the second. For example, when no hole was bored it took 8,827 pounds to pull them in the first test and only 7,613 pounds in the second. This can not be attributed to any difference in the spikes, but to the ties into which they were driven. Also, in the latter case the spikes were pulled soon after they were driven. The two series of tests, therefore, are not comparable with each other.

While the tests described show that boring holes into ties previous to spiking them is an improvement over the common practice in this country, experience abroad leads to the conclusion that even better results can be obtained by the use of screw spikes. To secure data for American operating conditions, screw spikes were used by the Forest Service in the Northern Pacific, Chicago & Northwestern, and Chicago, Milwaukee & St. Paul test tracks. In laying the Northern Pacific and Chicago & Northwestern tracks no screw spike boring or driving machine was available, so that the holes had to be bored and the spikes inserted by hand. In some cases the holes were not bored deep enough, and the point of the spike struck the base of the hole. On further tightening the spike the threads in the wood were destroyed. Furthermore, the holes were not in all cases bored vertically, so that the spikes were inserted at various angles. When the Chicago, Milwaukee & St. Paul track was put in place, a screw spike boring and driving machine was used, and the difficulties previously encountered were done away with. The machine drove the holes vertically and to a uniform depth, so that the spikes all had proper alignment and clearance. In every case the machine drove the spikes firmly into the tie.

The screw spikes used in the Northern Pacific and Chicago & Northwestern test tracks were driven through plates which did not reenforce the head of the spike against lateral thrust. After three years' service many of these spikes were badly bent, resulting in a widening of the track gauge (Pl. VI, fig. 1). In laying the Chicago, Milwaukee & St. Paul track, a plate with bosses for supporting the heads of the spikes was used, which it is believed will materially increase their holding power (Pl. VI, fig. 2).

In a large number of tests made at Purdue University, a part of which were conducted by the Forest Service,[1] it was found that screw spikes had from 1.7 to 3.8 times the strength of the common spike against pull, and from 1.2 to 2.4 times the lateral resistance of the common spike. The heads of the spikes were not supported in these tests.

An objection raised against the use of screw spikes is that it takes longer to insert them than to insert cut spikes, and that this at times delays the passage of fast trains. In laying the Chicago, Milwaukee & St. Paul test track this objection was partially overcome by spiking every third tie throughout the rail length, which permitted trains to pass, and afterwards spiking the remaining ties.

A further objection to the use of screw spikes is the difficulty of regauging the track when the rail becomes worn. It is possible that this objection may in time be overcome by altering the design of plates used with this type of spike.

[1] Fourth Progress Report of Tests on Treated Ties, by W. K. Hatt, Purdue University. Bulletin 124, A. R. E. and M. of W. Assn.

While the use of screw spikes in this country is still in its infancy and final judgment can not as yet be pronounced, it gives promise of overcoming the objections raised against the ordinary cut spike. If it succeeds in this it will unquestionably result in greatly reducing the mechanical destruction of ties.

HEWED VERSUS SAWED TIES.

Approximately 77 per cent of all ties purchased in 1909 were hewed. This proportion of hewed ties was less than in 1908, the same as in 1907, and greater than in 1906.[1] In the tie industry as a whole it is apparent that methods of manufacture are undergoing no general or permanent changes. The probable reasons are that the railroads obtain, either directly or indirectly through tie companies, a large proportion of their ties from farmers and small holders of timber who can not afford to saw them, and because the importance of utilizing timber to the best advantage has not yet been keenly felt. Under certain conditions the sawing of ties may be impracticable, as when, for example, only a few trees suitable for crossties are available, or when ties are cut from tops of felled trees. In such cases it is much better to utilize the wood by hewing it into ties than to leave it in the forest. The claim is often made that hewed ties are more durable than sawed ties because they shed water better. Nothing is known by the Forest Service to substantiate this impression. Even if untreated hewed ties should be more durable than sawed ones, this advantage disappears when the ties are treated. On the other hand, there are many serious objections to the use of hewed ties, and these will increase in importance in direct proportion to the number of ties treated with preservative. Chief among these objections are (1) unequal bearing afforded tie plates and rails, (2) lack of uniform volume, and (3) unnecessary waste of valuable material.

BEARING AFFORDED TIE PLATES AND RAILS.

The heavy tonnage on American railroads necessitates the use of some form of tie plate on practically all first-class construction. Hewed ties seldom offer a uniform bearing surface to the plate or rail, and unless specially adzed before placement soon wear unevenly and must be removed. An inspection of test ties on the Chicago & Northwestern track showed in many cases that one edge of the plate had cut into the tie to a depth of over one-half inch, while the other edge was not even flush with the surface (fig. 15). With sawed ties the bearing over the surface is more uniform and rail cutting is considerably reduced. The introduction of tie-boring and adzing machines is doing much to improve the bearing of plates on the ties and should cut down mechanical wear appreciably.

[1] "Forest Products, 1909," Bureau of the Census, Department of Commerce and Labor.

UNIFORMITY IN VOLUME.

Since tie inspectors offer no objection to, but rather favor, ties of greater dimensions than those specified, the tie manufacturer rarely hews a large log to the standard size. Thus the cubic content of hewed ties may vary from that of the uniform dimensions allowed to about twice the size specified. Practically all contracts for treating ties state that so much preservative shall be injected per cubic foot of wood. With hewed ties no treating plant knows accurately what this volume is until after the ties have been treated. To obtain the total quantity of creosote to be used, it is customary to figure that a tie will contain a certain amount of wood, and to multiply this figure by the number of ties and the amount of preservative to be injected per cubic foot. For example, to figure the amount of creosote needed

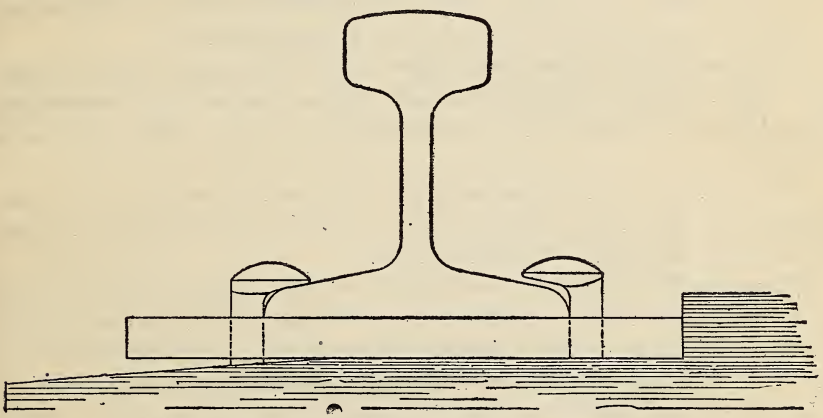

FIG. 15—Uneven bearing surface afforded by a poorly hewed tie.

to treat 1,000 crossties 6 inches by 8 inches by 8 feet with 10 pounds of oil per cubic foot, the calculation would be $1,000 \times 2.67 \times 10 = 26,700$ pounds. If the hewed ties average 3.2 cubic feet, though figured as of standard size, the total amount of preservative would be the same, viz 26,700 pounds, but the amount per cubic foot would be only 8.3 pounds instead of 10, as specified. Sawed ties are cut to more exact dimensions, and errors of this kind are improbable.

WASTE OF MATERIAL.

To hew a tie necessarily entails an enormous waste of material. (Pl. II, fig. 2). Based on actual field data the waste by hewing varies from 25 to 75 per cent.[1] Logs 15 inches in diameter furnish, as a rule, only one hewed tie, but if sawed they furnish two. Whenever possible the tie hewer selects trees of about 12 or 14 inches in

[1] Forest Service Bulletin 64, "Loblolly Pine in Eastern Texas, with Special Reference to the Production of Crossties," by Raphael Zon.

diameter. The waste of wood each year in the United States from hewing ties amounts to 285,000,000 cubic feet, a quantity equivalent to about 80 per cent of the total amount of pulpwood used in the United States in 1909. This is an absolute waste, as it is not even used for fuel.

ECONOMY THROUGH INCREASED LIFE OF TIES.

COST OF TREATMENT.

The total cost of treating ties can be divided into the following items: (1) seasoning, (2) labor, (3) fuel, (4) maintenance, and (5) chemicals.

The majority of ties now treated in the United States are air-seasoned prior to treatment. The cost of this varies with the kind of wood, season of the year, and geographical location. In general, however, it ranges from about 0.75 to 1.5 cents per tie.

Labor includes all forms necessary to the treatment, such as loading and unloading of ties in the yard, and for the tie plant and superintendence. It also varies considerably, but is here taken at 6 cents per tie.

Fuel is least in those plants which can use natural gas or oil and highest in those most remote from a source of supply, but ranges from about one-half to 2 cents per tie.

On account of the corrosive action of zinc chloride, the life of a plant using that kind of a preservative is usually reckoned as shorter than that of one using creosote; consequently, its depreciation is greater. The total cost of maintenance, including this depreciation, interest on the investment, etc., will usually range from 1¼ to 2 cents per tie.

Practically all of the ties now treated in commercial plants in the United States are injected with zinc chloride or with creosote, either alone or in combination. Only a few plants use preservatives like crude oil and mercuric chloride. It is customary to inject about one-half pound of dry zinc chloride per cubic foot of wood, although this varies at times from one-third to two-thirds of a pound. This salt costs from 3⅞ to 5 cents per pound. Creosote costs from about 6 to 10 cents per gallon in large quantities. It is customary in tie work to inject from 5 to 12 pounds of this oil per cubic foot.

With the above data the cost of tie treatments may be estimated. It should be borne in mind, however, that the figures given are general, and may not apply to all conditions. The total cost of treating ties is approximated in Table 10. These values are placed rather high, in order to make the data on financial saving more conservative. The most expensive treatment is one with a heavy injection of creosote. It would not be good practice to use

heavy injections where the ties are likely soon to be destroyed by mechanical wear; but, if the ties are hard and will be well protected with tie plates, this treatment should prove highly efficient. The cheapest treatment is the Burnettizing or straight zinc chloride, its cheapness being due to the comparatively low cost of the preservative used. This process would be most advisable where danger from mechanical wear is greatest, or where there is least danger of the salt washing out of the wood.

TABLE 10.—*Approximate cost of preserving ties (7″ by 9″ by 8′).*

Kind of treatment.		Cost of treatment.					
Preservative.	Amount injected (per cubic foot).	Seasoning.	Labor.	Fuel.	Maintenance.	Chemicals.	Total.
	Pounds.						
Creosote	10	$0.01	$0.06	$0.01	$0.015	$0.279	$0.375
Do	6	.01	.06	.01	.015	.168	.263
Zinc chloride	½	.01	.06	.01	.016	.070	.166
Creosote Zinc chloride	3 ½	.01	.06	.01	.016	.154	.250

INCREASE IN DURABILITY.

Unfortunately, reliable records on the life of treated ties in the United States are very scarce, so that it is largely a matter of conjecture as to how long the various processes now on the market will extend the natural life of ties. What information it has been possible to compile on the life of ties in service is given in Table 11. Some of these data are the result of European practice, and it is scarcely safe to draw definite conclusions from experience abroad, as both methods of treatment and conditions of use differ radically from those in this country.

Because of the lack of reliable data, nothing but estimates can be given concerning the life of treated ties in the United States. It is believed, however, that the figures given in Table 12 are conservative statements of what may be expected under normal conditions. Where figures are missing from the table, it means either that the woods referred to should not be treated (being either very durable in their natural condition or refusing to absorb preservatives), or that they are usually left untreated.

The life of 10 years credited to cypress refers to ties largely heartwood. If cypress ties are mostly sapwood they will probably last no longer than those cut from western pine. The reason why such long lives are given to treated red oaks and beech, and comparatively short lives to treated chestnut and white pine, is because the former are hard but readily permeable, and the latter comparatively soft and resistant. In general, a proper treatment with creosote will pro-

long the life of ties from 100 to 500 per cent. With zinc chloride, which is a soluble salt and tends to keep the ties moist, and hence weaker under repeated impact and compression, this increase in life will probably be somewhat less.

TABLE 11.—*Reported life of ties in service.*

Species.	Laid by—	How treated.	Life.	Source of information.
			Years.	
White oaks	Duluth & Iron Range Ry. Co	Untreated	8 to 9	2
Spruce	Union Ry. Co. (horse)	Burnettized	8 to 20	3
Pine (probably western yellow, longleaf, and piñon pines).	A., T. & S. F. Ry. Co	do	10½ to 15	1
	T. & N. O. Ry. Co	do	10 to 11	1
	H. & T. C. Ry. Co	Creosoted	19	1
Baltic pine	English railroads	do	8 to 18	4
Hemlock	C. R. R. of N. J	do	15½	1
	C., R. I. & P. Ry. Co	Wellhouse	10 to 15	1
	Duluth & Iron Range Ry Co	Burnettized	8 to 10	2
Tamarack	do	do	9⅝	2
	Pittsburg, Ft. Wayne & Chicago Ry. Co	Wellhouse	8, 8¼	5
Beech	French, German, and Austrian railroads	Untreated	4 to 5	3
		Burnettized	10 to 12	3
		Creosoted	18 to 30	3
Maple	C. R. R. of N. J	Burnettized	15+	7
	German railroads	do	16	6
Red oaks	Wabash R. R	do	5 to 6	8
	French and German railroads	Creosoted	19 to 25	3

1. Bulletin 107, A. R. E. and M. of W. Assn.
2. Proceedings A. R. E. and M. of W. Assn., Vol. V.
3. Transactions Am. Soc. C. E., Vol. XIV.
4. Transactions Am. Soc. C. E., Bulletin 895.
5. Proceedings Eng. Club of Philadelphia, April, 1907.
6. Eng. News, July 11, 1885.
7. Transactions A. S. C. E., 1905.
8. A. R. E. and M. of W. Assn., Vol. X, part 1.

TABLE 12.—*Estimated life of untreated and treated ties in the United States.*

Species.	Estimated life (all ties properly tie-plated).		
	Untreated.	Treated with 10 pounds creosote per cubic foot.	Treated with 0.5 pound zinc chloride per cubic foot.
	Years.	*Years.*	*Years.*
Black locust	20	.....	.....
Redwood	12	.....	.....
Cedar	11	.....	.....
Cypress	10	.....	.....
White oaks	8	.....	.....
Longleaf pine	7	20	.....
Chestnut	7	14	11
Douglas fir	6	15	11
Spruce	6	14	11
Western pine	5	17	12
White pine	5	14	10
Lodgepole pine	5	16	11
Tamarack	5	15	11
Hemlock	5	15	11
Red oaks	4	20	12
Beech	4	20	12
Maple	4	18	12
Gum	3	16	11
Loblolly pine	3	15	10

FINANCIAL SAVING.

The possible saving in money is unquestionably the most important factor in determining the advisability of treating ties. If it will cost more to use treated ties than untreated, few railroads will adopt tie treating. The most reliable data which it has been possible to collect are given in Table 13. In some cases it has been possible to verify the values for service by actual experience, as will be seen by a comparison with Table 11. The prices of the untreated ties are taken in practically all cases from the prices reported by the census.[1] In figuring the annual charges and savings, it is assumed that all ties are plated, the plates costing 25 cents per tie, and that the cost of placing a tie in the track is 15 cents. Annual charges are figured on the cost of the ties in the track, the computation being made by the following formula:

$$r = R\,\frac{1.0p^n.0.0p}{1.0p^n - 1}$$

Where

r = equivalent annual charge.
R = initial expenditure.
p = rate of interest (taken as 5 per cent).
n = term of years.

TABLE 13.—*Estimated annual saving due to the treatment of crossties with preservative and the use of tie plates.*

[In each case a charge of 25 cents per tie for tie plates and 15 cents for placement has been added to the cost of the tie, and is included in the computed annual charge.]

Species.	Estimated life.			Cost of ties.			Annual charge in track.			Annual saving of treated over untreated ties.	
		Treated.			Treated.			Treated.			
	Untreated.	10 pounds creosote per cubic foot.	½ pound $ZnCl_2$ per cubic foot.	Untreated.	10 pounds creosote per cubic foot.	½ pound $ZnCl_2$ per cubic foot.	Untreated.	10 pounds creosote per cubic foot.	½ pound $ZnCl_2$ per cubic foot.	10 pounds creosote per cubic foot.	½ pound $ZnCl_2$ per cubic foot.
	Yrs.	*Yrs.*	*Yrs.*								
Black locust	20	.....	.....	[2]$0.60	.....	.....	$0.080	.....	.....	.....	.....
Redwood	12	.....	.....	.53	.....	.....	.104	.....	.....	.....	.....
Cedar	11	.....	.....	.46	.....	.....	.103	.....	.....	.....	.....
Cypress	10	.....	.....	.41	.....	.....	.104	.....	.....	.....	.....
White oaks	8	.....	.....	2.60	.....	.....	.155	.....	.....	.....	.....
Longleaf pine	7	20	.....	2.52	$0.89	.....	.159	$0.103	.....	$0.056	.....
Chestnut	7	14	11	.44	.81	$0.61	.145	.122	$0.121	.023	$0.024
Douglas fir	6	15	11	.41	.78	.58	.160	.114	.118	.046	.042
Spruce	6	14	11	.49	.86	.66	.175	.127	.127	.048	.048
Western pine	5	17	12	.53	.90	.70	.215	.115	.123	.100	.092
White pine	5	14	10	.43	.80	.60	.192	.121	.129	.071	.063
Lodgepole pine	5	16	11	.46	.83	.63	.199	.113	.124	.086	.075
Tamarack	5	15	11	.41	.78	.58	.187	.114	.118	.073	.069
Hemlock	5	15	11	.33	.70	.50	.169	.106	.108	.063	.061
Red oaks	4	20	12	2.45	.82	.62	.240	.098	.114	.142	.126
Beech	4	20	12	.36	.73	.53	.214	.090	.104	.124	.110
Maple	4	18	12	2.45	.82	.62	.240	.104	.114	.136	.126
Gum	3	16	11	.52	.89	.69	.338	.119	.131	.219	.207

[1] Crossties purchased in 1909; Bureau of the Census.
[2] Prices quoted based on general observations.

Assuming the values given in Table 13 to be correct, a substantial saving may be effected with practically all species by preservative treatment. The choice of the species to be used is governed very largely by their availability. Some very desirable timbers, for example, the black locust, are very scarce, while practically all species have a limited range of growth, and transportation to distant points may make their cost prohibitive. While the table permits of some interesting comparisons of the relative cost of different species, the limitations of data of this character should not be overlooked. The following comparisons are based on the values given in Table 13, these comparisons being, of course, subject to limitations of the character mentioned:

(1) Untreated black locust is the cheapest tie that can be used, costing 8 cents per tie per year to maintain in service. The most expensive ties are untreated western pine, red oaks, beech, maple, and gum, costing respectively 21.5, 24, 21.4, 24, and 33.8 cents per tie per year to keep in service.

(2) Except for red oak, beech, longleaf pine, and maple treated by the Bethell process, and beech treated by the Burnett process, untreated black locust, redwood, cedar, and cypress are still the cheapest ties that can be used. On account of their increasing scarcity and cost, however, it is likely that this condition will not hold for long.

(3) Almost without exception a treatment with 10 pounds of creosote per cubic foot is in the end only slightly cheaper than a treatment with zinc chloride, assuming, of course, that the ties are adequately protected from mechanical wear.

(4) The best results in the treatment of ties are secured with red oak, beech, and maple. These ties when treated cost about 10 cents per tie per year to keep in service. The poorest results are secured from chestnut, spruce, and white pine, their charge being over 12 cents per tie per year.

(5) It appears that the prices now paid for ties to be treated need readjustment. Based on their intrinsic properties, red oak, beech, and maple ties are undervalued, while chestnut, spruce, and white pine are overvalued.

(6) When black locust, redwood, cedar, and cypress ties can not be secured at the prices given in the table and other woods must be used, it is in all cases cheaper to treat them than to use them untreated. The annual saving per tie due to treatment varies from about 2 cents for chestnut to 22 cents for gum.

(7) At 60 cents per tie untreated white oak is more expensive than any of the other naturally durable woods, since it costs 15½ cents per tie per year to maintain. Under the conditions assumed it is

cheaper to use inferior woods that have been treated than to use white oak untreated. When tie plates may be omitted on the white-oak ties, however, the annual charge will equal about 12 cents per tie per year, which compares favorably with the charges against treated ties.

RECOMMENDED PRACTICE IN PROLONGING THE LIFE OF TIES.

The information collected by the Forest Service during nine years of experimentation and observation furnishes, it is believed, sufficient data upon which to base a set of rules outlining good practice in increasing the life of crossties. A great deal of work remains to be done, and it will be a long time before the true worth of many of the processes now employed is known, but it is believed that the general recommendations here given, if followed, should make it possible to secure a longer life for wooden ties and a saving in the cost of track maintenance.

(1) The winter cutting of ties should be encouraged. It leaves the forest in better condition and the ties season with less danger of checking, insect injury, and decay.

(2) Preference should be given to sawed ties. These result in less forest waste and permit in general a more uniform bearing of the plate on the tie and the tie on the ballast. As a rule their use does away with the necessity for adzing and avoids the mechanical destruction resulting from an uneven bearing surface. Moreover, more sawed ties can be loaded on a cylinder truck, thus decreasing the cost of labor in the preservative treatment.

(3) As a general rule, all bark should be removed from ties immediately after they are cut. If, however, they caseharden or are otherwise injured they may be permitted to season with the bark on, but all bark should be removed before the ties are placed in the treating cylinder.

(4) If ties are to be adzed or bored, this should be done before they are treated.

(5) It is almost always cheaper and better to use treated than untreated ties. In localities where black locust, redwood, cedar, and cypress ties are available it may be cheaper to use these untreated than to use treated ties.

(6) In selecting ties for treatment, preference should be given to those which are hard and which absorb the preservative readily. Treated red oak, beech, maple, and gum ties will give better service than treated chestnut, spruce, and white-pine ties.

(7) Since sapwood is just as strong as heartwood and much easier to inject with preservatives, ties with a large amount of sapwood, provided it is properly distributed, should be preferred in preservative treatment to those with little or none.

(8) All ties should be thoroughly seasoned before treatment. Of the various methods of seasoning, air seasoning is preferred, because it is usually safer. If ties must be artificially seasoned, they should be heated at low temperatures and lose moisture gradually, to avoid serious checking.

(9) The sites selected for air seasoning should be free from weeds and decayed wood and well exposed to air currents. If possible, the yard should be covered with cinders. The ties should be elevated on creosoted stringers at least 6 inches above ground. The stringers should be laid close to the ends of the ties in order to retard checking.

(10) Ties cut from conifers are less likely to check during seasoning than ties cut from broadleaf trees, and in consequence can be piled more openly.

(11) If ties are seasoning too fast they should be piled closer together; if seasoning too slowly they should be piled more openly. Ties cut in winter can be piled more openly without danger of checking than ties cut in summer. The 8 by 2 form of pile will give general satisfaction; more open forms are the 7 by 1 and 7 by 2.

(12) Serious end checking, if not controlled by methods of piling, can be retarded by driving S-shaped irons over the check.

(13) The length of time ties should season before treatment will vary primarily with the species of wood, form of pile, and period of the year. In general, ties cut in spring and summer will be seasoned sufficiently for treatment by the end of the following autumn; ties cut in early spring will be seasoned sufficiently by the following early autumn; the seasoning period varying from about two to four months. Ties cut in autumn and winter will be sufficiently seasoned by the end of the following spring, the period varying from about five to eight months. The periods necessary to season dense ties like the oaks will generally be from two to three months longer than those just given.

(14) A preliminary soaking of ties in water to increase their rate of air seasoning and their absorptive properties is not recommended unless it can be done without extra expense. The slight advantages gained are not sufficient to warrant an appreciable expenditure of time or money.

(15) When ties are received at the treating plant they should be piled in groups according to the way in which they take treatment, those which absorb large quantities of preservative being piled separately from those which are difficult to impregnate. The species which should comprise the various groups are not as yet as well known as is desirable, but the distinction can at least be made between those that behave very differently under treatment. Only thoroughly seasoned ties should be treated. It is bad practice to

mix seasoned and green or only partially seasoned ties in one charge. The aim should be to treat all ties in a charge with approximately the same amount of preservative.

(16) At present it is not known definitely what preservative or process is most economical in all cases. Under heavy traffic, where the ties wear out before they rot, treatments with zinc chloride or light treatments with creosote may be advisable. When the traffic is light, heavier injections may be better. If the ballast is wet or moist, creosote is to be preferred to zinc chloride.

(17) No matter what kind of ties are treated or what preservative is used, at least all of the sapwood and as much of the heartwood as possible should be impregnated with the preservative.

(18) If ties are to be treated with zinc chloride, and absorb the preservative readily, the solution should be made dilute, and as much as possible injected. This is better practice than having the solution more concentrated and forcing only a limited amount into the outer fibers of the wood.

(19) The treating plant should be in good operating condition before any ties are treated. Leaky valves and pumps should not be permitted, and all gauge scales should be accurate and the pulleys and floats running free. After treatment the excess preservative should be returned to the same measuring tank from which it came, and the reading corrected for temperature if necessary. If the float system is used, the amount of absorption should be determined by measuring the difference in the height of the float before the preservative is run out of the tank and after it has been returned to it.

(20) While track scales are generally desirable for determining absorption, they can not be depended upon if the ties are to be steamed or boiled in oil.

(21) As the composition of the preservative is very likely to change after a number of treatments, it is highly desirable to have it analyzed frequently to see that it meets the specifications.

(22) Creosoted ties which are not to be used immediately should be piled solidly (9 by 9), while those injected with zinc chloride should be openly piled, to permit of rapid seasoning. In doing this the precautions against too rapid seasoning should be observed. Zinc-treated ties should be seasoned before being placed in the track, in order to avoid as far as possible the leaching out of the preservative and corrosion of the spikes.

(23) If a nine-sixteenth-inch diamond-pointed cut spike is driven into a previously bored hole three-eighths to seven-sixteenths inch in diameter it will hold better than an ordinary cut spike driven directly into the tie.

(24) From the results of tests thus far made it appears highly desirable to use screw spikes whenever possible. When they are used holes should first be bored deep enough in the tie to allow a space between the base of the hole and the point of the spike, or the hole may be bored entirely through the tie.

(25) It is not possible at present to say which of the various types of tie-plates are best. The data thus far secured, however, point to the advisability of using heavy metal plates with flat or only slightly corrugated bottoms. When screw spikes are used, the heads of the spikes should be protected from lateral thrust by a boss of metal fitting snugly under the head.

APPENDIX.

PUBLICATIONS OF THE FOREST SERVICE DEALING WITH THE PRESERVATION OF CROSSTIES.

Bulletin 41. Seasoning of Timber, by Herman Von Schrenk.
50. Crossties and Rail Fastenings, with Special Reference to Treated Timbers, by Herman Von Schrenk.
64. Loblolly Pine in Eastern Texas, by Raphael Zon.
Circular 39. Experiments on the Strength of Treated Timbers, by W. K. Hatt.
46. Holding Force of Railroad Spikes in Wooden Ties, by W. K. Hatt.

OTHER PUBLICATIONS DEALING WITH WOOD PRESERVATION FROM WHICH MATERIAL WAS SECURED.

Wood Preservation, by W. F. Sherfesee and H. F. Weiss, Report of the National Conservation Commission.
Forest Products No. 8, Bureau of the Census: Crossties Purchased in 1909.
Proceedings and Bulletins of the American Railway Engineering and Maintenance of Way Association.
Transactions of the American Society of Civil Engineers.
Proceedings of the Engineering Club of Philadelphia.
Proceedings of the Wood Preservers Association.